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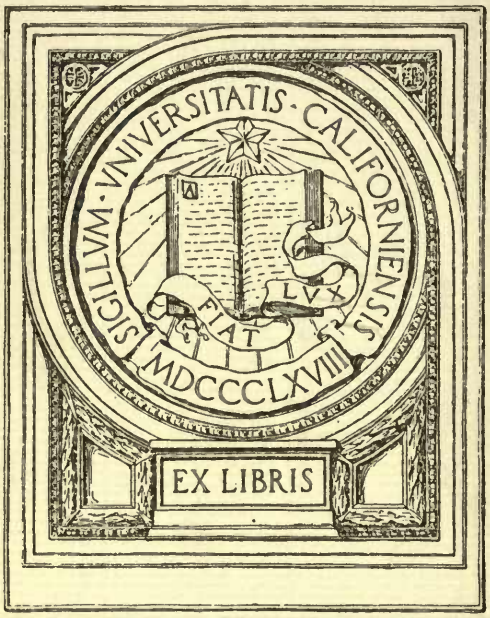
Wonderland of Work

NEW REVISED EDITION
WITH ADDITIONS BY
JOSHUA ROSE M

IN MEMORIAM
J. Henry Senger



THE

WONDERLAND OF WORK.

BY

C. L. MATÉAUX

AUTHOR OF "HOME CHAT," "AROUND AND ABOUT OLD ENGLAND," "TIM TRUMBLE'S LITTLE MOTHER," ETC., ETC., ETC.

NEW AND REVISED EDITION.

WITH ADDITIONS BY

JOSHUA ROSE M.E.

AUTHOR OF "THE COMPLETE PRACTICAL MACHINIST," "THE PATTERN-MAKER'S ASSISTANT," "THE SLIDE-VALVE," ETC., ETC., ETC.

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IN MEMORIAM

Prof. J. Henry Senger

CONTENTS.

OLD KING COAL AT HOME AND ABROAD.

PAGE

In the mine—At work—Stavers of the mine—"Heavers" "holers," and "putters"—Weighing coals—Screening coals—Various modes of working mines—Mining accidents—The rescue—The Davy lamp—Primeval forest of the coal period—What is coal?—Coal seams—Early use of coals—The power of coals..... 1

THE LIGHTS OF OUR GREAT CITIES.

The production of gas—How it is purified—Gas-holders—Retorts and condensers—Will Murdock's hat—Coke and its uses—How coal-tar is produced—The first gas balloon—Street-lighting—The electric light—Jablochkoff lamp..... 23

STRIKING A LIGHT.

The tinder-box, flint and steel—Swedish matches—Match-making—A visit to an English manufactory—Scorching—Filling frames—Drying-room—Dipping—Stamping boxes, etc., etc..... 36

CONCERNING IRON AND STEEL.

The first blacksmiths—The "black country of the North"—Blast-furnaces—Casting pig-iron—"Puddling"—Superstitions about iron-work—Shaping iron—Rolling sheet-iron—Casting iron in moulds—The grain of cast-iron—How a fork is forged—Forging under the steam-hammer—Nasmyth and his steam-hammer—Water mining in Sweden—Smelting with coal—The Bessemer process—The value of a little bit of steel—What is manganese—Herr Krupp's factory at Essen—Gun-making at Woolwich—The eighty-ton gun—How anchors are forged..... 41

THE "TOY SHOP" OF THE WORLD.

About a pin—Pin-making machines—Pin-sticking machine—The largest pin-factory in the world—Needles and how they are made—Straightening, tempering, pointing, and finishing—Files and file-cutting—The file-cutter's tools—File sharpening with the sand-blast..... 82

OUR KNIVES AND FORKS AND SPOONS.

How pen-knives are made—Forging, filing, and tempering table blades—Grinding and polishing blades—Cutting ivory for handles—Boring the handle—Stamping spoons—Forging spoons and forks—Steel forks—At the electro-plater's—Polishing, batteries and troughs, soldering with the blowpipe—Turning oval dishes—Ancient and modern Sheffield..... 99

MAN'S TOOLS AND THEIR USES.

The various kinds of hammers—Straightening saws—How work is measured one-thousandth of an inch—The use of callipers—The surface plate—Tool-grinding—The emery grinder—The polishing wheel—The lathe and its uses—Wood-turning—Cutting-tools—The engine lathe—The chucking lathe—The iron-planing machine—Effect of punching iron—How coins are stamped—The milling-machine—Drilling-machines—The wood-worker's boring tools—Drills and braces—Drilling square holes—Boring and turning mills—Some of the uses of iron—Nail-makers—Tacks and wood-screws—The thread of screws—Taps and how they are used—Machine-made screws—The screw-forging machine and its furnace 110

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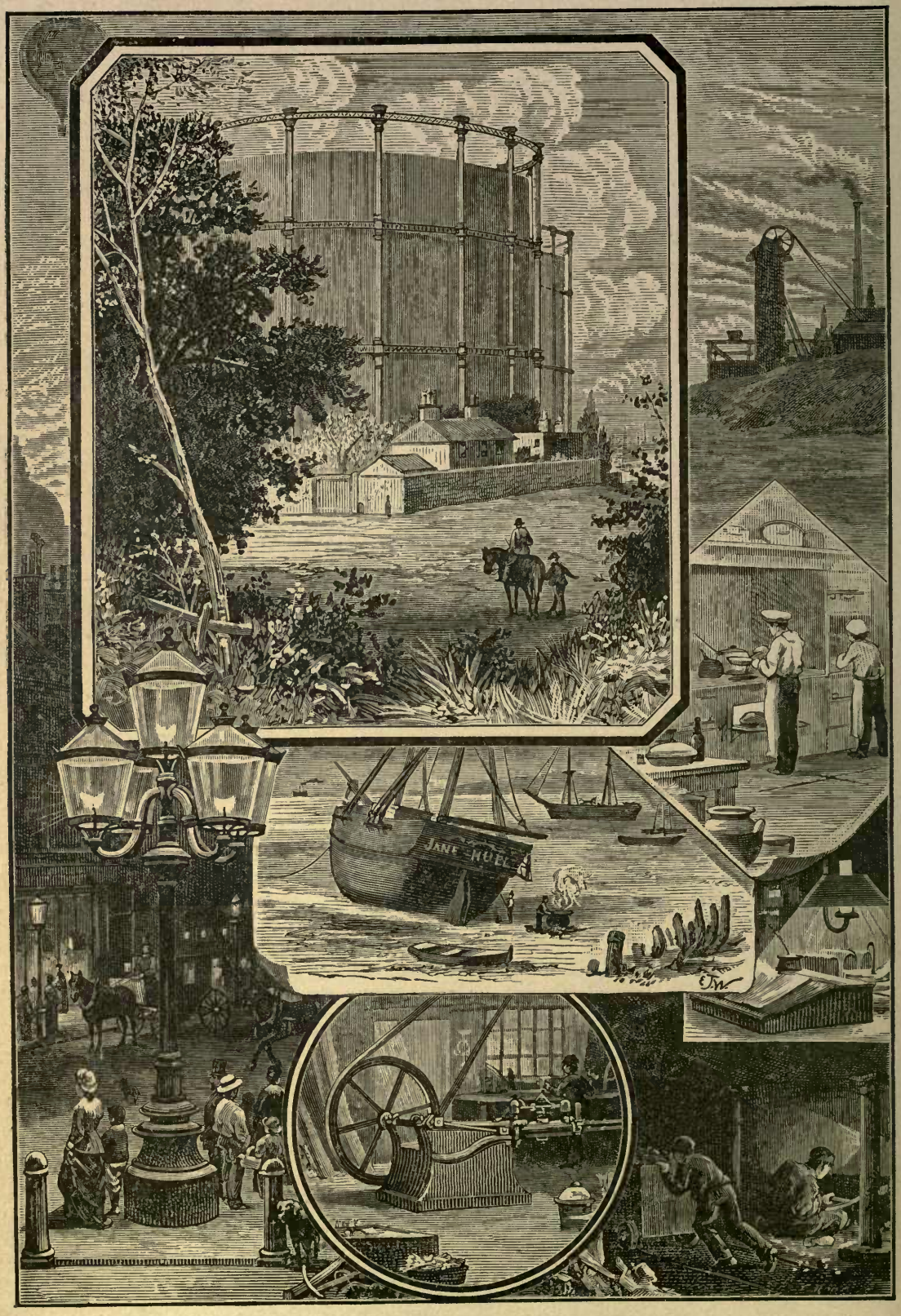


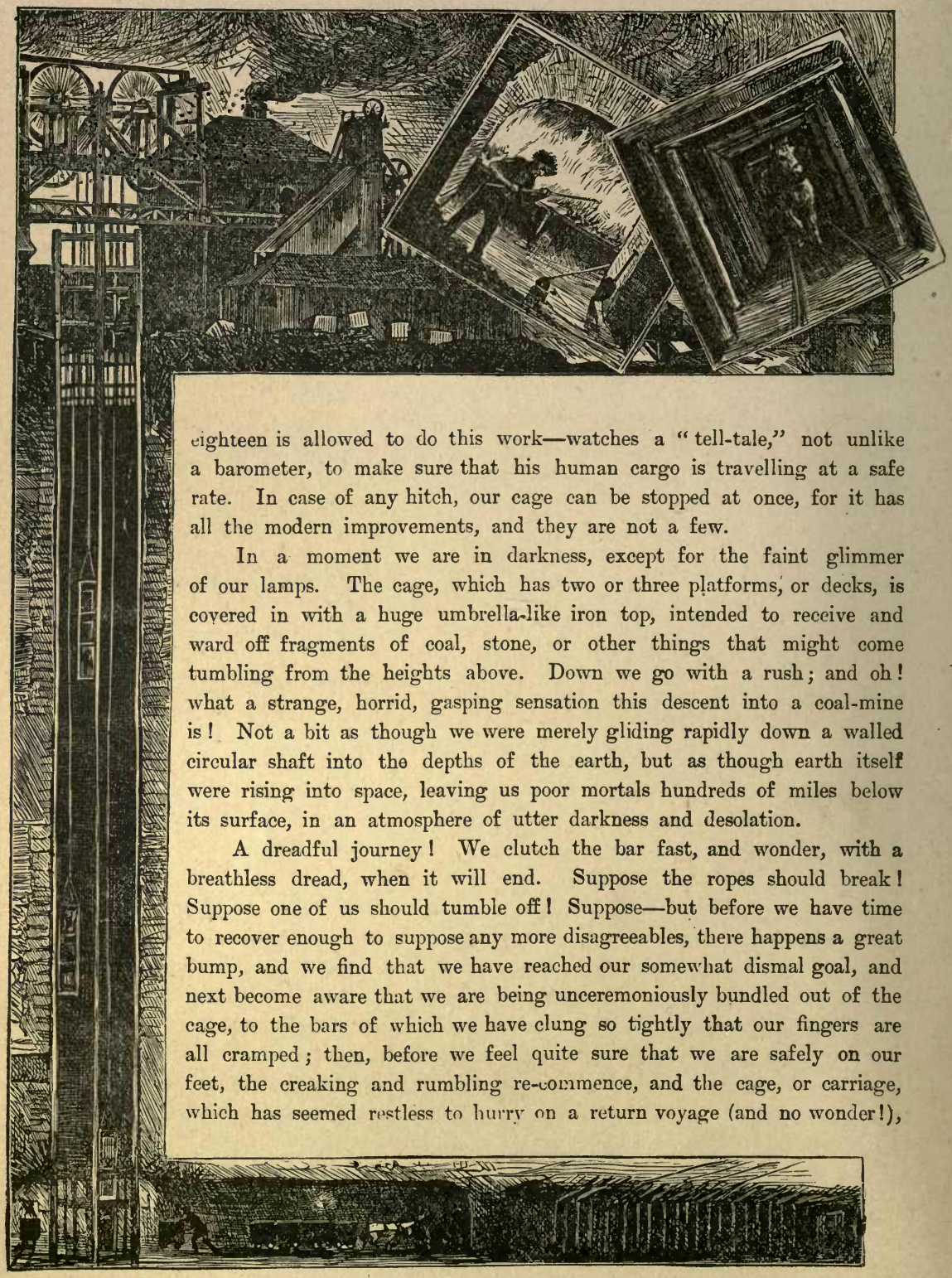
KING COAL UNDER DIFFERENT ASPECTS.

"BY A SEA-COAL FIRE."—*Shakespeare.*

THE WONDERLAND OF WORK.

OLD KING COAL AT HOME AND ABROAD.

IF you would visit the domains of King Coal you had better first slip on one of those loose grey flannel suits over your own, and hide your hair under a not particularly becoming leather head-dress; for we shall most likely get very dingy ere we return from the underground journey I propose taking you before beginning any explanation. This journey is down—down—down into one of the dark pits so numerous in the Black Country, which is rich also in iron ore, and the limestones that help to purify it when they are melted together in any of those tall and smoke-dried blast-furnaces which, for economy and convenience' sake, cluster as nearly as possible about the pits' brows. The huge circular mouth of a pit-shaft is but a dismal and melancholy-looking place, not at all tempting to a looker-on. Yet here we are, and down we must go; so take your safety-lamp, step on to the "cage," or "hoppet," grasp tight hold of that iron bar, and bid good-bye to daylight and fresh cool air, while a bell gives a signal, a stationary engine instantly unwinds the iron or steel ropes (found to be much safer for this work than hempen ones) that hold our cage firmly enough, no doubt, though we are relieved to hear that there is strong brake-power available, and that the engine-man—no one under



eighteen is allowed to do this work—watches a "tell-tale," not unlike a barometer, to make sure that his human cargo is travelling at a safe rate. In case of any hitch, our cage can be stopped at once, for it has all the modern improvements, and they are not a few.

In a moment we are in darkness, except for the faint glimmer of our lamps. The cage, which has two or three platforms, or decks, is covered in with a huge umbrella-like iron top, intended to receive and ward off fragments of coal, stone, or other things that might come tumbling from the heights above. Down we go with a rush; and oh! what a strange, horrid, gasping sensation this descent into a coal-mine is! Not a bit as though we were merely gliding rapidly down a walled circular shaft into the depths of the earth, but as though earth itself were rising into space, leaving us poor mortals hundreds of miles below its surface, in an atmosphere of utter darkness and desolation.

A dreadful journey! We clutch the bar fast, and wonder, with a breathless dread, when it will end. Suppose the ropes should break! Suppose one of us should tumble off! Suppose—but before we have time to recover enough to suppose any more disagreeables, there happens a great bump, and we find that we have reached our somewhat dismal goal, and next become aware that we are being unceremoniously bundled out of the cage, to the bars of which we have clung so tightly that our fingers are all cramped; then, before we feel quite sure that we are safely on our feet, the creaking and rumbling re-commence, and the cage, or carriage, which has seemed restless to hurry on a return voyage (and no wonder!),

A PIT-SHAFT, VENTILATING FURNACE, AND TRAP-DOOR.

is with two other figures in it, swinging above our heads, and off to the upper earth, where, to tell the truth, it is just possible you may wish yourself safely landed again; for of all the damp, dismal places and "uncanny" sensations, nothing beats the first few minutes spent in a mine. Yet cheer up, fellow-traveller! Your eyes will soon get accustomed to peer through the darkness, and your ears to distinguish the various noises and far-away rumblings that fill the place with a strangely mysterious commotion. Yonder we see a great coming and going of shadowy men, of clattering laden corves, or tubs, and trotting ponies; we hear shouting resounding through echoing galleries, which appear to branch off from a main one, and vanish into blackness in every direction. Altogether it is at first quite bewildering, yet in a very little time the darkness seems to clear away somewhat, so that we scarcely need peer at our lamps so anxiously before preparing to follow a dusty young sojourner in these underground regions, who marches us to the principal roadway, along which stretches a line of tram-rails, the use of which we presently discover.

THE HEWER AT WORK.

For some time our onward progress is easy enough; we are getting used to the close atmosphere, and the tiny twinkling lights begin to look quite natural and homely. Our grimy guide is ready with his answers to all our inquiries, but presently we have to stoop and dive, to avoid a rough knock now and then about our heads or shoulders; next we are troubled by a most peculiar noise in advance of us—it sounds like distant thunder. We peer anxiously into the darkness, but can make out nothing, only that the noise is rapidly advancing straight in our direction, and is increasing to a most fearful din—closer and closer. What dreadful thing is going to happen? At last we cannot forbear shrieking out an inquiry to our guide, who shrieks back coolly enough that it is only a train of heavily-laden railway rolleys full of corves, or measures, of coal, that go up and down this tramway. "There is a return one passes them just here. Better step back out of their road: there ain't no room for them and us at a time. Get back sharp! or"—the rumbling hollow sound drowns the rest of his remark, and we look about us frantically anxious to oblige, for the noise is deafening and the danger uncertain. However, we retreat close to the rough wall, and find, much to our relief, that cut into it, no doubt to provide for such a dilemma as ours, are a series of recesses, into one of which any ordinary body can pop, while a long and heavily-laden train of corves—which hold from ten to

twelve cwt., and which we notice run upon four sharply-pointed wheels, set very closely together that they may be tilted—pass us on their way to the mouth of the shaft.

When we have waited for a convoy of empties to clatter and rattle by in the opposite direction, we step out again and resume our voyage of discovery, leaving what may be termed the high-road—"jinney" our conductor calls it—of the mine to venture into all sorts of dark narrow workings, wriggling ourselves into various dismal holes and corners, that we may get a better idea of what those poor fellows have to endure who toil, half clad and wholly covered with coal-dust, until they are as dingy as niggers—struggling in heat and darkness for the black treasure which is to carry warmth and light and comfort to the busy world above.

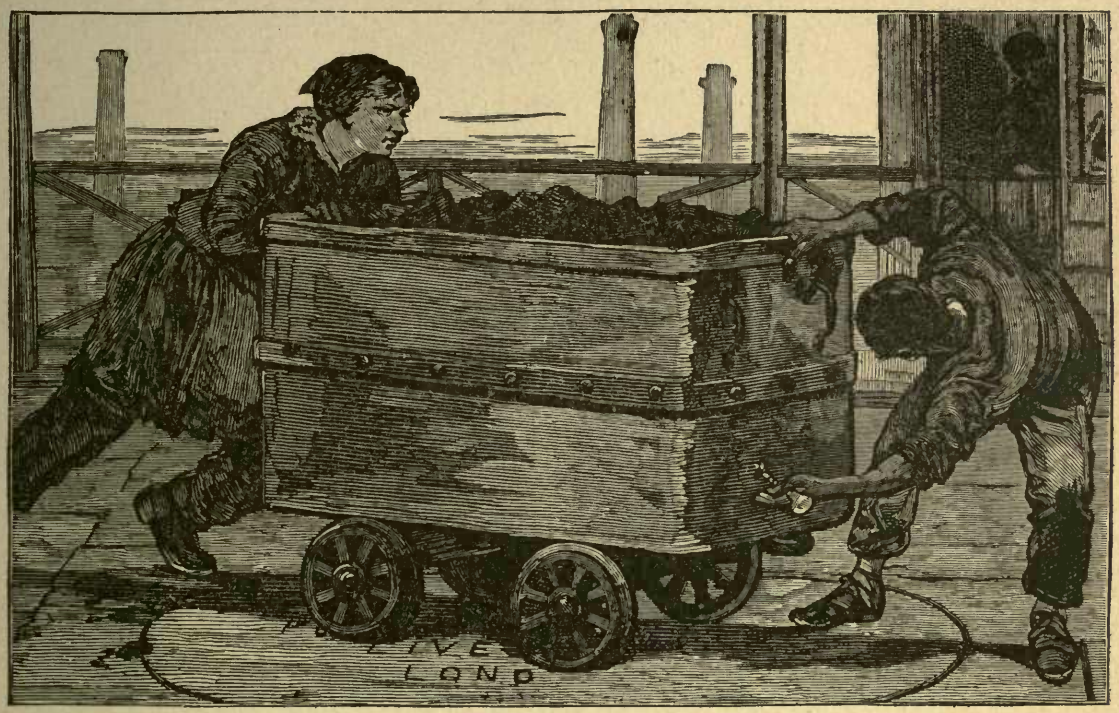
We are told that in some parts of the mine these strong "hewers"—the actual diggers, I mean—can loosen as much as six tons of coal a day from the firm bed in which it

STAVERS OF THE MINE—"HEWERS," "HOLERS," AND "PUTTERS."

has lain undisturbed for so many ages; but the progress is much more slow in what is known as "low travelling," where the vein of coal is very narrow—sometimes not much more than two feet thick; then the poor collier has a dreadfully hard task to accomplish. The only possible manner by which, pick in hand, he can work his way into the vein is by lying face downwards, and stretched full length upon a kind of low iron tray, or cart, which he calls a "jackram;" this he propels forward with his bare toes, painfully hammering and picking his way as he moves thus uncomfortably, creeping snail-like into apertures too small to admit a man's body in any other position.

When these poor hewers, "holers," or "undergoers," have done loosening enough coal in any particular vein, the "putters" take the work in hand. They are usually very young fellows, whose business it is to load the broken coal into big corves, or baskets, which by dint of pushing and pulling they drag off to the more open spaces where it s possible to get the assistance of ponies; for, as we are shown, many of these useful animals, mostly imported from Norway and Iceland for the purpose, are kept in the mine. Some of them, indeed, never go out of it. Here they have stables, hay, and fodder; fresh water and corn are sent down every day, and a horse-keeper looks after their health and comfort; so they are not so badly off as we might fancy, though after all it must be sorry work for a poor horse never to gallop over the pleasant greensward, or

to feel the fresh air and warm sunshine he would enjoy so much, but only to perambulate long galleries, with full or empty rolleys at his heels. However, we must remember that habit goes a long way, and that the poor half-blind creatures are doing good service in this dark underground world, where, as we know, they relieve the "putters" of their heavy "upbrows" of filled corves. These "putters," or "hurriers"—many of them boys, who have often to crawl almost at full length, owing to the lowness of the excavations—we are told generally form a kind of partnership. Thus, when two lads are of about the same age and strength, they always work together as "half marrows," and share the profits equally; when one is bigger and stronger than the other, he is called the "headsman,"



A BOY AND WOMAN ON THE BROW OF THE PIT WEIGHING COALS.

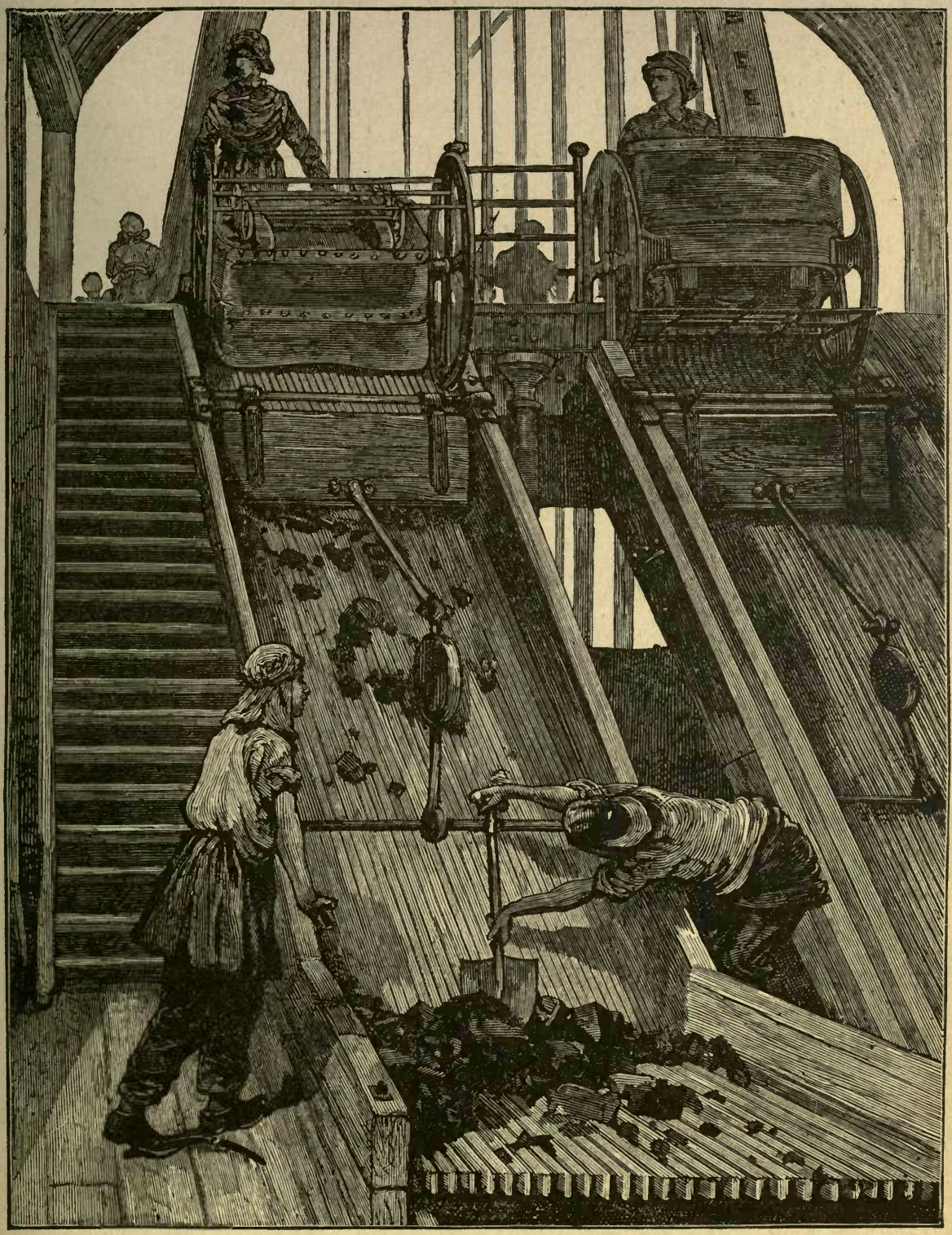
the weaker assistant is dubbed his "foal," and of course, as he brings less strength and power to the business, he has to be content with a smaller proportion of their joint earnings. Time was when we might have seen girls at this hard work; men mined the coal, and women "carried" loads heavier than themselves. It is well we need fear no such sight now, for the law has put a stop to that, though it does not keep them from the pit's mouth.

Having seen the coals hewn and "put," we follow our sedate and shadowy leader, to watch the great corves placed in the care of the "cranesman," who carefully numbers each load before seeing it laden on to the rolley, or waggon, which is to transport it to the bottom of the up-shaft, where it is taken charge of by two young but strong-armed "onsetters," whose business evidently is to hook on the full corves and start them on their upward career, and to unhook the empty ones when they come swinging lightly down again after their journey, which has been performed at

a wonderful rate. As all these loads are "banked," that is, arrive upon the platform on the pit's brow, the corves at once pass over a weighbridge, and the quantity which each contains is ascertained before it is emptied, or "tipped," on to a big heap outside. Each fresh arrival brings with it a numbered tin or brass ticket, bearing the number and name of the hewer who has sent it up from the depths; and as the corve is almost instantaneously weighed, a boy appointed for the purpose calls out the name and the amount of coals answering to it, which are set down carefully in a weigh-book, and that there should be no chance of mistake, a "check-weighman" is always on the spot to verify the weighing in the name of the absent underground worker. The contents of the corves, which have been thus disposed of in the "tumbling" or tipping cage, are now to be "screened," that is, to go through a kind of sifting process in a large screen, somewhat resembling a monster and massive gridiron, its bars from an inch to an inch and a half apart. All the big pieces of course stay in here, while those that can fall through do so, passing into another "screen" to be sifted into "nuts" by dropping through its bars, which are only half an inch apart. Even the remainder of mere coarse dust, or "slack," which is again sorted by boys and women, finds a ready market, being used in coal-ovens, iron-furnaces, and for the manufacture of patent "briquettes," or fuel of various kinds. Next, when sufficiently screened, the pieces are tipped into a flat shoot, and from thence fall clattering into the waggons or trucks which are to convey them by road or rail to various parts of the kingdom; some economical purchasers, however, bring their carts to be filled at the pit's mouth, and quantities are carried off to the barges or vessels which are to take them away by water.

It used to be a very common thing to meet by the banks of the Thames or other rivers with many busy bands of "coal-whippers;" they were usually composed of nine men, one taking the lead: some of them did the shovelling of coals from the holds of the vessels into big baskets, which others hauled up by means of ropes and pulleys, ready for their mates who, wearing great flapped leather hats, carried them off on their backs and emptied them into the long open "lighters," which were to bear them to the several coal-wharves. It was a hard and ill-paid work that now is seldom heard of—at any rate, on a large scale; for a floating derrick and steam-worked arms can do the business in far less time, and in a much more effectual manner than the poor coal-whippers. But stop! We are travelling too fast, forgetting that we are in our coal-mine, and far from the shining Thames.

We have not as yet seen through the glorious domain of "King Coal;" we have not done walking through his narrow roads, where the deeper we go, the hotter and more oppressive grows the atmosphere, though, being a properly-regulated mine, it is only at the rate of one degree for every sixty feet we descend. Sometimes we come to quite a neat and shiny little black drawing-room, the walls of which are clearly composed of layers and strata of ironstone, blue clay, and shale; but in other places we as suddenly come to where some poor "undergoer" is working in such a narrow "vein" that he has to lie sideways. We can see little of him but his bare dusty feet as he works painfully at making a long thin hole in the narrow seam of coal, into which he drives his sharp iron drilling-tools as deep as they will go; then he toils with short stout picks and hammers, over which he has not enough command for the work he has



WOMEN SCREENING COALS AT THE PIT'S MOUTH.

to do, for he cannot swing them as he ought. Having to work them without any proper leverage no doubt adds to his fatigue, yet on he has to drag his weary way, loosening and driving out as best he can the coal which rattles about him.

There are different modes of working mines, which our guide tries to make as clear to us as possible. In the Shropshire method, which can only be adopted with "thin coals," as each "chamber" is emptied and cleared of its riches it is deserted, and the wooden beams or props—usually formed of the trunks of small oaks or of sturdy English larches—of which there seem to be hundreds about, being required for use elsewhere, are withdrawn and carried away, leaving what is called a "goaf," or empty space, that sooner or later falls in, often producing a kind of earthquake in the land above, tippling over the poor little hovels built upon it. In some parts of Staffordshire there are entire districts where whole rows of houses can be seen half sinking into the ground, or uncomfortably perched at every angle but the right. They are the wretched habitations of the colliers digging and delving below—men who get good wages, but are not over-provident as a rule, partly because of a system which long prevailed of getting all the things they required on credit, or "truck," from a middleman, and thus being too often overcharged and cheated out of their hard-earned money.

In straight or narrow drifts, levels are fixed in various positions, and many rough pillars of coal are left standing to support the roof. This is termed the "post and stall" method, and is so managed that all these posts or pillars of coal can be one day worked back upon and removed. We can fairly stand up here to look about us; but the noises we hear are rather startling, until we are informed that those mysterious hollow bangs, sounding like distant thunder, and filling the air with sulphurous smoke, are caused by workers "holing" the coal-bottoms.

This, we soon find out, means that after the coal has been cut away some ten feet wide and five or six feet deep, the collier drills deep openings in the coal walls, as close up near the roof as he can get at; then he carefully fills these holes with gunpowder, and next proceeds to blast them in such a manner that all the coal about them shall be shattered, loosened, and easily broken up into bits ready to be at once carried off by the "putters" and "hurriers." It must be a disagreeable and grimy task, filling eyes and mouth with dust and smoke. No wonder that the men engaged in it speak in such hoarse tones, or that they are more like dark spirits of the mine than honest mortals at their daily work. And no wonder either, that of late years this dangerous method of blasting coal should have been almost altogether discontinued in all the most important pits, and the pick and wedge alone resorted to.

On our way in and out of these mysterious galleries and "chambers," our guide turns his light on many workers, who to our unaccustomed eyes all seem to have a sort of weird and wistful look—though I believe that miners get to like their occupation; indeed, there is a saying, "Once a miner, always a miner." We meet with "shifters" and "wasters" and "way-cleaners," who, bustling or peering about, with the light in their lamps gleaming like fire-flies, seem to be busy everywhere. Boys, who are not allowed down until thirteen years of age, are clearing away the stray bits of coal or shale that may have dropped in the way; others sweeping and removing coal-dust, and keeping the tramways clear of

obstructions which might cause accidents. Then, too, the lately cleared "chambers" must be watched, and supported with sturdy beams of timber placed across their openings, lest they should suddenly fall in and block up the paths and passages about them.

There goes the "butty," who, it appears, gives out the work, and the "doggy," who sees that it is properly done—so at least our smudgy guide calls two shadowy figures yonder, talking to a third man, evidently a visitor from above, known as the "banksman," who keeps accounts and receives coals, and seems a generally useful person. But I expect these are local terms, and would not be understood by the colliers of different counties.

One most important part of the whole business, concerning the welfare and safety of the miners, is that relating to the drainage and ventilation, which should be kept as perfect

THE RESCUE—ONLY JUST IN TIME.

as possible, and be constantly noted and reported upon; for even with the best care and arrangements a great and unexpected increase of noxious gases sometimes takes place, owing to the sudden loosening and release of long-stored-up masses of coal. It has happened, even in well-ventilated mines, that a single careless stroke has opened a "blower." Neither you, nor I, nor any of those hundreds of toilers would ever see daylight again if the ventilation of this underground world chanced to be neglected or obstructed for ever so short a time. Damp unwholesome gases, gunpowder, and the breath of so many creatures would soon become unbearable, and cause suffocation. Even as it is, over a thousand fatal accidents each year are computed to happen to the poor workers, from one cause or another, in the mines of the United Kingdom. One of the most painful accidents, our guide reminds us, happened in the Hartley Colliery, where 204 unfortunate men in the mine were starved to death through the iron beam of the pumping-engine falling into the shaft and blocking it up.

The guide tells us that in one year—1878, for instance—our supply of coals, which consisted of 132,612,063 tons, cost 1,413 lives; that out of every 336 workers one was killed, and some of them in a very shocking manner. It seems strange that so many men

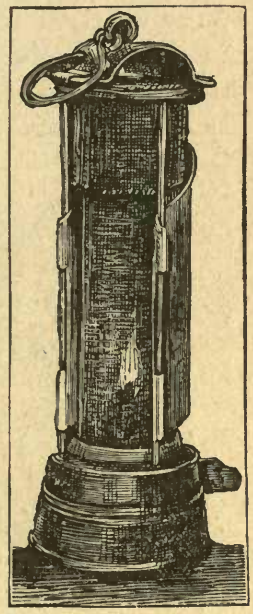
should be found to undertake cheerily such a business. This reminds me of what a visitor to the mine wrote some years ago concerning a miner's dangers and difficulties :—

"A large and increasing part of the British population lives a hazardous, uncouth, and cheerless life in the bowels of the earth, further than Lynceus ever saw, and deeper than Cyclops ever descended. So little are we of this upper earth accustomed to dive below the surface, that in order to form any idea of the level at which a collier does his daily work we must measure it by something above our heads. We must suppose our wives and children on a level with the cross of St. Paul's, perhaps higher, and ourselves daily descending by ropes to the sewers of this city. We shudder at the thought of hardy islanders suspended over the precipice in quest of birds' eggs. The collier's descent is often deeper, and his doom, should he fall, more certain. Should he miss a step at the 'bank,' should the rope break in his descent, should a wheel in the engine be put out of gear or a peg out of place, or should the boy at the pit's mouth be inattentive for a moment, the next instant basket, rope, and man lie an undistinguishable mass at the bottom of the shaft. But that is only one, and not the greatest of his dangers. The miner moves in an atmosphere into which a million chinks and pores distil a deadly vapour. The very air he breathes is a magazine of destruction. Wherever he extends his labours he lays bare a new surface and starts a fresh foe. In these upper regions the natural currents of air diffuse and carry off all noxious effluvia as fast as they arise; but the natural atmosphere of these wonderful vaults is itself a poison, and the vital air we breathe must be artificially introduced in quantities sufficient not only for human consumption, but for the expulsion of local gases. A strong current of fresh air must be brought down a shaft, conducted through the whole mine, carefully sweeping every corner and recess, and so passed up another shaft to the surface. If this current be insufficient, or accidentally interrupted, the foul vapours accumulate, and a naked candle, a spark, or a lighted pipe explodes the whole mine, burning, suffocating, or dashing to pieces every living being in its range. The explosion, which drives out by the pit's mouth the whole mass of air within, entails a reaction not less deadly. The 'after-blast' finishes the work of destruction. The list of perils is not complete unless we add that everywhere are suspended over the collier's head vast masses of material ready to fall and bury him at his work."

As I am thinking sadly over this, and rejoicing that matters are somewhat mended, our guide is volunteering information on the subject.

Before the steam-engine helped to drain mines and to carry away coals, excavations were carried on to a much more limited extent; yet even then the spirit of the mine was generally rampant at the intrusion of mortals into his "beds," and being lighter than the rest of the air, he often hid in what is called the "forehead," or upper part of the chambers of the mine, that he might work men evil, as he could easily do, being invisible to all eyes, and only to be detected by fire, which is the weapon with which he destroys. The poor miners were terrified at the enemy they found pervading every corner. They beat him off into the air, or, knowing no better way to defeat him, "fired" his principal hiding-place every morning. This they did by fixing a lighted candle to the end of a long pole, which they, lying full length on the rough floor, extended carefully towards the "forehead" where the evil thing hid. Of course, this inflamed fire-damp instantly caught at the small flame as it reached its neighbourhood,

expanded, blew a great angry blast, and vanished in flame and fury, defeated for the time being, much to the relief of the prostrate miner, who usually donned wet clothes for the encounter, dreading to be burnt and scorched by the hot breath of his retiring enemy. But sometimes this same dreaded damp was too strong to be attacked by hand thus, and then the operator stood at a safe distance and passed his candle slowly towards the invisible foe—that, luckily, is always to be found up in the air, just as water is to be looked for at our feet—by means of a cord and a catch fixed at the other end of the gallery. This mode of exploding the inflammable gas was known as the "firing line" explosive. We have heard so much here by this time about the danger of fire-damp and explosive gases, that we look with renewed and lively interest at the ingenious little lamps we carry, the like of which have saved so many precious lives. The "Davy" and the "Geordie" are those mostly in use, and if the collier, that most reckless of beings, could only be persuaded to use them more carefully, and not to open them on every occasion when he wants to smoke a forbidden pipe, these lamps would be of still more value in defeating the foe than they are at present.



THE DAVY LAMP.

Sir Humphry Davy's invention is certainly very simple and easily understood. In it, the flame is surrounded by a perforated metal case of fine wire gauze, the holes in which are large enough to allow the light to pass out, but not enough heat to affect the air about it, in which, as we know, explosive gases too often abound. Sometimes, however, if the safety-lamp passes through the fire-damp, some of it gets inside; but there it burns, for it is caged and cannot get out, or do mischief to the bearer, although perhaps it will put out the light in the lamp, burning with a strange flame itself. Fortunately, this peculiar gas—scientific men call it light carburetted hydrogen, and tell us it is composed of one part carbon and two parts hydrogen—is not to be met with in every mine, being more abundant in coals of the bituminous or caking kind. It is altogether a stranger in some Scotch mines, though it is far too generally found in those of Northumberland, Durham, Cumberland, Yorkshire, and Staffordshire, where it works great harm, in spite of all the care taken to foil it.

We see nothing of the kind for ourselves in this dry, well-ventilated mine, but our guide assures us that in some out-of-the-way recesses, where the air cannot circulate freely, a great quantity of most peculiar-looking soft fungi grows in masses, clinging especially to the timber beams supporting the sides and roof. He describes it as more like soft white wool than anything else, and says that at a single touch it drops, and vanishes like some magic thing. A noisome vegetation truly, and worthy of the spirit of the mine, so fond of the hidden corners of his dreary underground domain, but whose presence is not a pleasant thing for visitors to remember at present.

Suddenly we find ourselves directly under the upcast shaft—every colliery owner is bound to provide two means of egress—which leads to the world of light and life. We can almost fancy, as we peer up it, that we see a round piece of the blue sky which we shall be so glad to

greet again; but as we know this shaft has to do with the important subject of ventilation—which is carried out by means of "brattice cloths," or timber partitions, up one side and down another of which the air is constantly travelling—we are content to step back and follow our leader through a little open door, then along a close, muddy, dark passage, then through another little door, which bangs to behind us as we suddenly find ourselves standing in such a violent draught that we are glad to clutch our hats fast and scamper across to the other side, where a tall dingy stoker, lightly dressed after the manner of his kind, stands armed with a long iron rod, with which he is stirring up a fine roaring, flaring fire in a furnace, near which is the wide fire-brick chimney or shaft which carries up the hot air to the pit's mouth.

I am very glad to say we have met neither women nor little children through the whole of this underground journey. But there are plenty outside, working about the screens and tips; bare-armed women wearing the same dress as the men we have left below, and some smoking short pipes, so that we have to look in their blackened faces before we can see any difference. As they sift and fetch and carry, we observe that they are smart in the matter of necklaces and ear-rings and cheap finery. Children under ten are not allowed here at all, but must go to school. Poor mites! times are changed for the better, as far as they are concerned. Before 1844 both they and their mothers worked like slaves in the depths we have just left.

As we have learnt something concerning colliers of to-day, let us here make mention of the underground workers of the era of

THE COLLIERY GIRLS.

King James I. These poor men seem to have had very hard times, not only from the danger of the mines—for there were no kinds of engines or safety-lamps with which to defy the evil spirit of the depths—but they were harshly treated, especially in Scotland, not being allowed to leave an employer without giving a twelvemonth's notice. When the regular colliers began to get scarce, the coal proprietors were allowed to seize upon any unfortunate homeless vagrant they met with, and send him down, willing or unwilling, to toil in the mine, to dig out the coal, to attend to the pumps, or to clear the way, for as long as it suited these unprincipled masters, which might be for a lifetime. And terribly hard toil, too; for the law decreed that "all cole-hewerers should worke all the six dayes of the weeke, and if any lyed idle they should pay twentie shillings for everie day not employed, and suffer other punishments of their bodies." This was but one of several hard laws, which remained unaltered until the closing year of the last century.

If after seeing so much of it we seriously inquire "What is coal?" we are told by many earnest students of the mysterious Wonderland of Nature that it is the mineralised remains of a strange vegetation which must have grown and flourished for a very long period in the remotest ages of our world—when the conditions of the earth were entirely different from what they are now, and man himself had not yet been created: for the warm and humid atmosphere in which such gigantic and luxuriant ferns, conifers, palms, and other like trees could alone exist and grow everywhere, was not fitted to be breathed by such delicate lungs as those possessed by any human creatures. There could have been no such thing as what we term "climate" in those days, or rather there must have been one settled climate all the world over, for exactly the same kind of fossil vegetable remains are found scattered far and near, and hidden away in all latitudes, from Spitzbergen to the centre of Africa, from Greenland to Guinea—everywhere the remains of this mysterious "carboniferous flora" are found to be precisely of the same kind, which could not have happened had there not been one equal temperature. There can be no doubt that the vegetation of those times was something very different from what we can possibly imagine growing in our temperate land, as indeed it could not grow *now*. Monster trees pressed close together, filling the solitary and untenanted forests with rank foliage that spread with a mighty luxuriance. Ferns, bushes, shrubs, mosses, and water-plants —things we now think of but as pretty and insignificant—were then important parts of the landscape. Those slender little weeds, for instance, country children call "mare's-tails," and love to twist and twine in their pinky fingers, were then represented by such tall trees as these Equiseta, which, as you see, were not at all unlike giant asparagus, while its new buds spring up from the ground round about it, growing as that does by means of an underground stem (see page 14).

What a wonderful sight a flourishing forest on such a scale would have presented had any mortal eye been there to view its marvels. In every direction spread crisp, green lycopods, such as we now cultivate as delicate little plants—insignificant but pleasing. Then, they spread far and near some eighty feet about the mighty Sigillarias, nursed in constant heat and moisture, rising until they had attained to over a hundred feet or more; and at their base, pressing closely about the monster stems, grew dense thicknesses of herbaceous plants

A PRIMEVAL FOREST—A PORTRAIT ON COAL OF THE FIRST KNOWN REPTILE—EQUISETA AND TREE-FERNS

and weeds of all kinds, ferns and clumps of soft moss-like plants which caught and held the moisture, while twining tufts of strange form, and wreathing garlands, flung their tendrils from trunk and stem, forming altogether a scene of which only travellers in the tropical forests of the East may perhaps get a faint image; for there, in the moist, hot depths, are still to be found many of the same giant kinds of palms, aloes, tall water-rushes, and quaint-branched, many-leaved shrubs, half hidden in rank, tangled undergrowth of weeds, which must in that dim old time of the Carboniferous era have been as general in what is now Europe as elsewhere on the great wide wonderful world.

Yet though these old forests must have been so marvellously strange and luxuriant, it could have been but an unsatisfactory beauty. The tall tree-ferns, with their lace-like leaves (of which three hundred species have been discovered in the different coal-series of Europe, though they now only yield about fifty), and numerous other trees and plants—all most graceful and fair to see—

COAL-SEAMS

THE FOSSILISED TRUNKS OF TREES FOUND IN A COAL-SEAM.

produced no flower or bud; of pure white or glowing purple blossom there was not one, nor sweet ripe fruit or shining scarlet berry. There was no man, singing bird, or other breathing creature on land as yet to need or enjoy such things, and such things were not. The only sign of life was in the waters, though swamp and pool and river lay hidden and overhung by the giant green reeds, and but little life was there—perhaps a few strangely-formed fish, and certainly a quaint reptile, which has received the hard name of Archegosaurus, of whose singular pointed head I can show you an undoubted likeness—a strange fact you may think, but here it is as it was discovered in 1847, hidden in the depths of the coal-mines of Saarbrück, near Strasburg. Some remains of this same extraordinary creature have also been discovered in America (page 14).

The question suggests itself, if there was no living being alive at this Carboniferous period, how can the wisest teacher of the present day possibly know what the world was

like, or be even sure that such things as we have been describing ever existed at all? It seems such a strange lesson. How could they have learnt it? Who could have taught it them? No one; they learnt it, as you, as all may do, of the coals. Yet the coals, in smell, feel, colour, or appearance, do not give the slightest clue to such a strange and unlikely history, and certainly in no way remind us of stately pines or waving palms or graceful ferns. Surely this solid black stony substance which we are so grateful for, and use to such advantage, never formed any part of these things. Besides, how *could* anybody know of their origin now, even if it had been so in the darkness of time?

The answer we require to this question is read in the coals themselves, for in them hide, as any of us must have seen, seeds, and clear impressions of leaves and fragments of woody stems. Even more than that, for in the depths underground are sometimes found the entire fossilised trunks of just such trees as I have been telling of. They have not seldom been discovered clustering together in the very centre of a bank of coals. The Equisetum—that is, the giant "mare's-tail" of geologists—has been thus found, standing quite erect and free of its surroundings. Sir Charles Lyell tells of a bed of coal in South Staffordshire, where, within a quarter of an acre, there were discovered no less than seventy-three stumps of trees, all their roots still attached to and forming part of a seam of coal ten inches in thickness, resting on a layer of clay two inches thick; and under all this was a second forest, resting on a bed of coal from two to five feet deep; and again beneath this lay a third forest, with large stumps still in the places where they had grown. Sir Charles mentions also that when in Nova Scotia he found in one portion of some coal-fields, which were 1,400 feet thick, sixty-eight different levels, presenting evident traces of as many ancient forests. The trunks of the trees still showed the roots which had held and nourished them when they spread fresh and green over the fair land.

It has been proved by actual inspection and measurement of existent coal-seams, that in the region now known as the United States the forests and thickets of the Carboniferous period extended over more than 190,000 miles; in Queensland over 8,000; over 1,000 in France; and 500 in Great Britain. But very much higher numbers are doubtless to be safely inferred, for it is believed that, in the case of Great Britain, for instance, such forests covered all the ground, extending from the north of what is now known as Edinburgh to below the Wash, from the hills of North Wales to lands stretching far beyond the Channel which separates us from France—for these same geologists tell us that the Straits of Dover did not exist even in the wonderful "tertiary" period which they picture. But after all, how was it that these varied monster trees, these wide-spreading ferns and rushes, and soft green mosses, close-packed and luxuriant as we know they grew to be in the damp and heat and sunshine, ever became coal? By what wonderful process did they pass from their soft vegetable nature into these innumerable layers of hard, stony, black substance, without which so many homes would be comfortless, industry come to a standstill, and our Wonderland of Work scarce worth visiting?

Strange—nay, marvellous—as such a transformation appears to be, a little explanation shows the apparent miracle to have come about in a straightforward and natural way enough, for these dense masses of thriving vegetation, springing up rapidly in a close, moist atmosphere, as rapidly arrived at maturity; then quickly faded, withered, and died;

first the leaves were scattered in many a shower, then their fibrous trunks fell among them, while the soft, swampy ground formed a rich-yielding hotbed, upon which they soon decayed, changing into a mere tangled mass of vegetable matter, over which occasional layers of mud or clay were brought and left by retiring waters. It is evident also that at long and uncertain intervals of time this yielding, rotting surface must have sunk and settled somewhat, and that shallow waters washed in, bearing great deposits of various sands and pebbles, which dried up and formed hard layers of stony bands, compressing and holding fast the vegetable matter beneath, which was thus covered in by a curious process of natural chemistry, and slowly but surely changed into what we call coal, as surely as the mud hardened into slate or shale in which there was a total absence of ironstone, while the deposits of sand and pebbles grew into rocks, as though more safely to hide and guard the mysterious transformation going on in the Wonderland beneath.

That there should be less doubt of the "how" of this strange beginning, we have but to examine some of these bits of the once soft and impressionable "shale" which has evidently pressed on the decaying mass over which it stole, drying so rapidly that it had time to catch many an impress of lace-like fern, of broken twig, or ripe dry seed, which, once modelled, was never to be effaced from the surface of the shale—where we see it now, its tracery or modelling as clear and defined as though it had been taken yesterday. Yes, as Charles Kingsley, in reasoning upon this strange transformation of mere vegetable matter into coal, reminds us, we may find, even in England, every gradation between coal and forest. We may see the forest growing in its bed of vegetable mould. We may see the forest dead and converted into peat, with stems and roots in it, that again into sunken forests, like those to be seen below high-water mark on almost every coast on this island, where we may find gradations between them and beds of lignite, or wood-coal, then gradations between lignite and common or bituminous coal, and then gradations between common coal and culm, or anthracite, such as is found in South Wales and many parts of the world. But, you may inquire, how is it possible, according to known natural laws, for vegetable matter to become coal? The chemist answers this by showing that wood can become lignite, or wood-coal, by parting with its oxygen in the shape of carbonic acid gas, or what the miners call "choke-damp," and then it can pass into ordinary bituminous coal. This explanation sounds rather scientific, perhaps, but it really is very easy to understand; and it is as easy to believe that what *can* be done, *has* been done, in this great Wonderland of Nature which lies hidden under our feet. Yet that all doubt should be set at rest on this important matter, experiments have been made to demonstrate plainly the process by which these mineral treasures were formed. To prove how this transformation originally took place, an apparatus was used by which a mass of strongly compressed vegetable matter, placed in an envelope of moist clay, was exposed to a long-continued warm temperature. The means used allowed the escape of the gases and vapours which must arise from such a mass of vegetation, but to escape only in such a way that the decomposition of the organic matters it contained took place in a warm medium, saturated with moisture and under a pressure which effectually prevented the separation of the elements of which it was composed. By these means various very curious results were soon arrived at. Thus the sawdust of different kinds of wood produced substances resembling various

kinds of coal — some bright and shining, others of a duller, harder sort, which seems clearly to explain the reason why coals are so often found in strips of dull or shining veins, varying of course according to the timbers and vegetables of which they were originally formed.

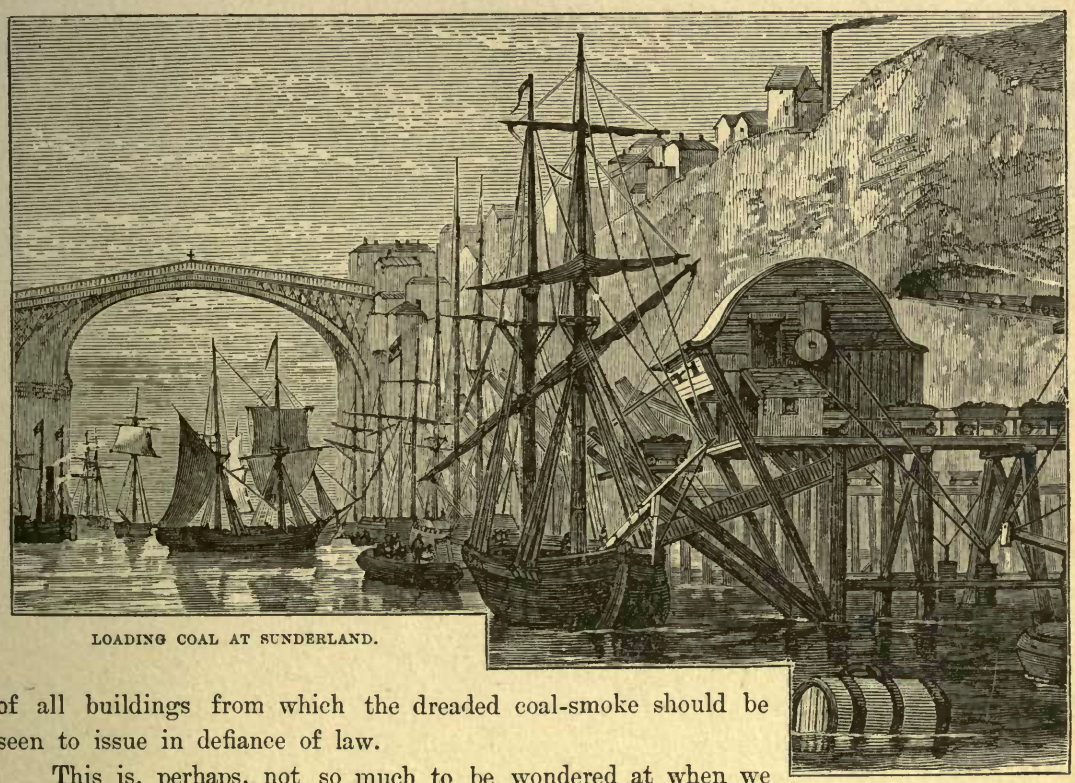
The period during which these several primary forests continued to grow, to flourish, and to decay is unknown, except as far as can be realised from the known thickness of various seams of coal in different parts of the world. At Dudley, in the Midlands, there is one thirty-six feet thick; near Ashby-de-la-Zouch, one of twelve feet thick; near Edinburgh is a ten-feet seam, and in Poland one of forty-eight feet. How often such forests were overflowed and destroyed by the waters rising and spreading over a sinking area, and how often they again sprang into being and life and beauty when these waters receded, and the ground was once more raised and levelled, is to be estimated by the number of "seams" which can be counted in a section of the coal-measures, each seam representing the growth of one of these apparently useless forests, which no man then enjoyed, but which are now storehouses of light and heat and resistless steam-power.

Of course all these precious deposits lay at first in flat and even though hidden beds, on Mother Earth, until disturbed more or less by certain volcanic movements from within, which shook and changed their places and positions, sending some lower and raising others at all sorts of angles, even to her surface, where they must, we should imagine, soon have attracted the attention of mankind; men, however, being as yet mere hunters, and subsisting on fruits as well as on what wild animals they could slay, cared more for such hard stones and flints as they could chip into weapons or hatchet-heads, by means of which they would kill their prey, or cut down the timber with which they were liberally surrounded.

The woody nature of coal can be best detected in lignite, or brown coal, found in such immense quantities in America, India, China, and elsewhere, and which we owe to later periods, when forests sprang into being where once had been seas, they in turn leaving their deposits to be gradually buried in the sediments of other lakes and seas, which have vanished long ages since. The hard dry "anthracite," of which there are immense quantities in Pennsylvania and other lands, are generally much more tumbled about in their hidden beds than the soft or "bituminous" coal we burn in English grates. Yet they were certainly formed of the same unlikely materials and in the same way—that is, by a certain amount of heat from below and pressure from above; but in the anthracite regions violent volcanic action going on in their close vicinity must at some far-off time or other have shaken them to their very depths, and broken and unsettled the coal-measures, drying and hardening their veins, by draining and expelling the bitumen and oily matters they originally contained.

But now we are about to pass from the mysterious Carboniferous period of its history to that in which coal first concerns our own—not so very long since as you might imagine, for while timber was plentiful, coal had but little chance of being appreciated; and it was not until the fourteenth century that the freemen of Newcastle, finding that the people of Edinburgh were trading in it, thought of obtaining a charter giving them the sole right of mining and selling the hitherto almost valueless "coles" that lay thick in every direction about their feet. Thus arose a traffic in "sea-borne cole"—that is, coals

"borne" by ship from Newcastle to other ports—but the prejudice against the new fuel was so strong that but little was bought or sold for a long time. Even when the brewers, dyers, and other workers would gladly have used it, as wood was becoming expensive, a great outcry arose, folk declaring that its fumes poisoned the air, and would certainly cause a pestilence in any neighbourhood where it was consumed. Then, as it still found more customers than was expected, King Edward, urged by the citizens, issued a proclamation sternly prohibiting its use to all but smiths, and not only fining those who persisted in burning such obnoxious stuff, but sanctioning, if not ordering, the destruction



LOADING COAL AT SUNDERLAND.

of all buildings from which the dreaded coal-smoke should be seen to issue in defiance of law.

This is, perhaps, not so much to be wondered at when we remember that in those days of no chimneys, ordinary people sat over a "hearth-stone," on which burnt logs of wood, or even peat, the smoke of which curled about their heads, or passed out of door or window when they chanced to be opened. This, of course, could not be possibly endured with coal-smoke; chimneys had to be built, and houses altered to admit of them, which necessity of itself was looked upon as a grievance. As one of the time wrote indignantly: "There are old men yet dwelling in the village where I remaine, which have noted the multitude of chimnies latelie erected, whereas in their young daies there were not above two or three, if so manie, in most country townes of the realme, the religious houses and manour-places of their lordes alwaies excepted; but each one made his fire against a reredosse" (an open fireplace without a grate).

In the early days of Queen Elizabeth the laws remained so stringent on this subject that a few shiploads of coal passing from Newcastle to London represented the traffic in the

despised treasure; and when later on its value and general uses began to be better understood, we read that it might never be burnt during the sitting of Parliament, lest its fumes should affect the health of country members, used to pure wood or charcoal. Stowe tells us of "the nice dames of London, who would not come into any house or roome where sea-coles were burned, nor willingly eat of meate that was either sod or roasted with sea-cole fire;" though thirty years later the same writer bewails that through the great "scarcetie of wood, the inhabitants of the Citie of London," as well as others, "are constrained to make their fires of sea-cole, or pit-cole, even in the chambers of honourable personages, and through necessitie, which is the mother of all arts, they have of verry late yeares devised the making of iron, the making of all sorts of glasse and burning of bricke, with sea-cole or pit-cole." Very surprising; yet I wonder what these same "nice dames," or even the devisers of iron, would have thought could they have known that in 1877 no less than 18,250,110 tons of that metal would be smelted by means of "coles" in the United Kingdom, and that its mines furnished 134,610,763 tons, to be used for all kinds of purposes, in many manufactures, railroads, gas-works, steam navigation, mining operations, besides our own and many of our foreign neighbours' household requirements and comforts. Yet as perhaps this large number of tons may give but a poor idea of the quantity of "coles" they represent, let me quote a lecturer on the subject, who pictures it as all built into a wall, thirty feet wide and thirty feet high, which if commenced in London might reach to Rome. Even the quantity, 8,591,683 tons, which was brought into London in 1877 would suffice to build just such a wall, reaching the fifty-two miles from London to Brighton.

But to return to those old times for a few minutes. Let us note that, as the population increased, and as the various forests, from being constantly stripped and cut down, began to grow bare of the timber which had served their every purpose, English people began to find that "sea-cole" must be endured; they next realised it was a very useful and good thing, that did not kill men off as fast as might have been expected. Still, its progress in public favour was so slow that it was only when steam-power was invented, and gaslight became general in large towns, that a complete revolution took place in industries generally. Mines were opened in every direction, and an immense and profitable coal trade was developed. For in curious contrast to those few solitary vessels trading in "coles," which were carried by pack-horses to the ships or purchasers, are the estimates I have mentioned of the quantity of this invaluable mineral now used throughout the world, nearly one-half of which has hitherto been raised from the mines of the United Kingdom. The most important "coal-fields," or "basins," are those of the great Northern District, including all the "fields" north of the Trent; those of the Central District, including Leicester, Warwick, Stafford, and Shropshire; and those of the Western District, including North and South Wales, Gloucester, and its neighbourhood. In all these "fields" the coal is found stowed safely away in a number of layers, or beds—"seams" I should term them—varying from a few inches to many feet in thickness, and which are all separated from each other by the layers of slaty clay, or "shale," which first covered them, and of "grit," a coarse hard sandstone; while, underlying these strata, a bed of mountain limestone usually extends, often stretching beyond the coal-field, and rising to the surface of the earth about it. The coals themselves vary in kind and quality, the most important being the ordinary bituminous sorts, which

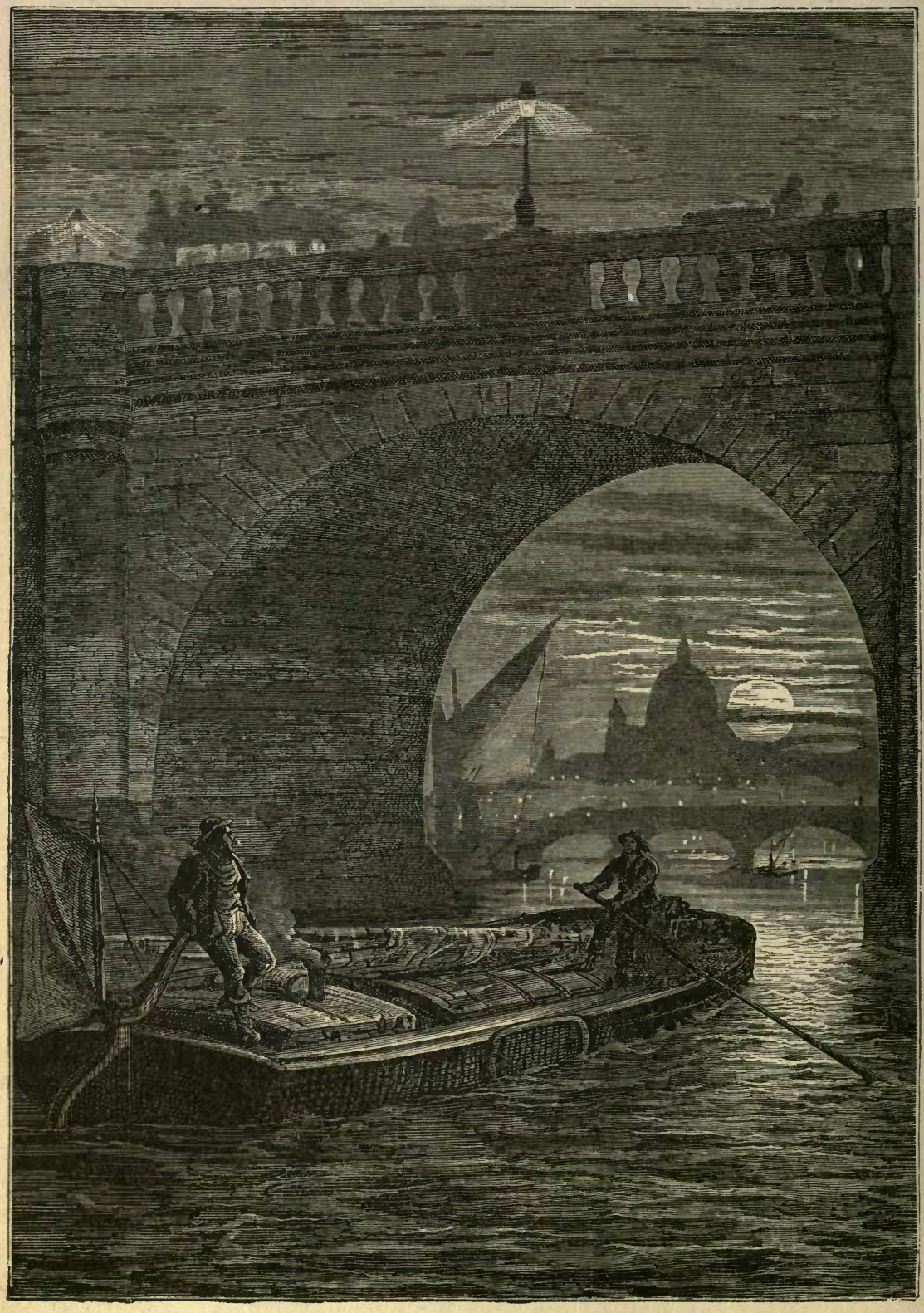
contain a large proportion of gas, tar, paraffin, and other substances, all of which have their uses in commerce.

Among the varieties of this kind of coal is the "cannel," "candle," or "parrot" coal, so called because of the cheery chattering noise it produces, while giving forth a very bright flame. Cannel coal is very much patronised by the gas-makers, who, I am told, can extract the best gas from this particular kind of "black diamond," which is not very black, and breaks into dry lumps, somewhat resembling jet, which is one of the "lignites." Curious things have been fashioned out of it. In the Exhibition was shown a great, well-polished cup, or tazza, sent by the Turners' Company, as a specimen of their skill with the lathe and tools specially ground for this task. No doubt it was a very difficult piece of workmanship to execute, as coal is so brittle that without the utmost care it would fly off in every direction.

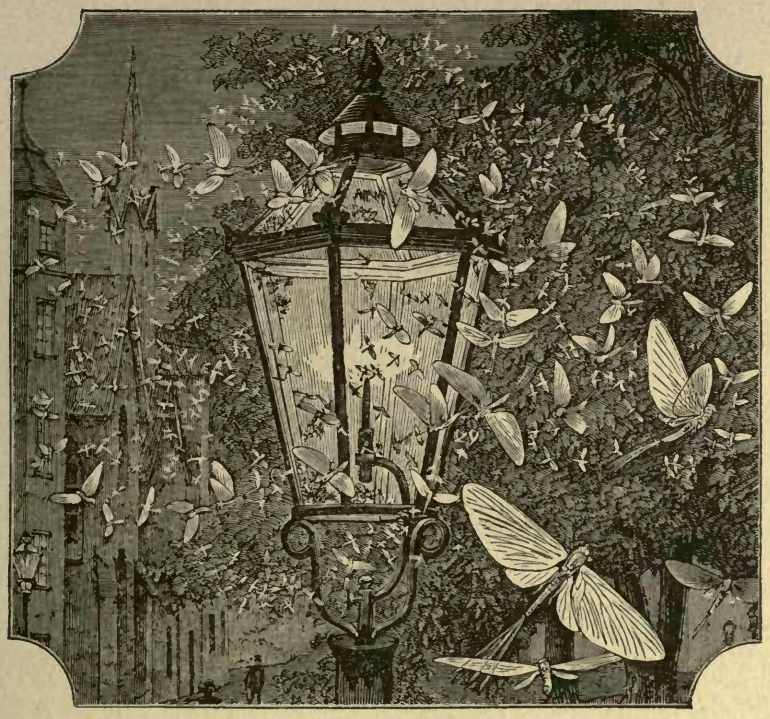
Of course we all know that the value of coal depends upon its combustible and inflammable properties. Parliamentary reports tell of seven millions of tons being annually consumed by the gas and water companies of the United Kingdom. Of its use as mere household fuel I need not speak, but as our great manufactures and mining works are dependent on it in the form of the mighty power it aids in producing, I may as well tell something of the strength to be obtained from coal as represented in the never-tiring steam-engine, whose very essence and soul it is.

A thinker who has written on this subject has tested the power of steam, "that giant spirit of all work," by comparing it with the task done by a worker on an ordinary treadmill. Reckoning that a man weighing 150 lbs. (about the average) lifts his own weight 10,000 feet in a day—that is, he raises one pound 1,500,000 feet in that time. It is understood also that a certain quantity of coal in the form of steam will elevate its own weight a certain height. We can easily understand, therefore, that if one bushel (representing 84 lbs.) of coals raises any object say one foot from the ground, and that in some of the improved engines this "duty," as bushel measurement is called, is equivalent to the result of raising 125,000,000 lbs. one foot high, or one pound 125,000,000 feet high, the division by 84 gives nearly a million and a half feet as the work of one pound, which is the same as the result of a day's steady trot on the treadmill. Therefore one pound of coal would represent that day's work and wage, if such undesirable work were paid for in anything but weariness and shame.

Our authority next estimates a period, often a lifetime, of hard muscular toil, lasting for twenty years. Reckoning 300 working days to the year; that represents altogether 6,000 days, or 6,000 lbs., or, to sum it up, three tons of coals as represented by steam-power. Therefore we can but come to the conclusion that every three tons of coal is the convertible representative, or rather equivalent, of one man's lifelong muscular activity—a fact which must make us feel a sort of wondering respect when we look at a solid lump of coal, every cubic yard of which weighs over a ton, and remember that a block some twelve feet high, the base of which is only a yard square, has more "work" in it than many a man's life-labour.



WATERLOO BRIDGE BY NIGHT.



THE LIGHTS OF OUR GREAT CITIES.

"Prime cheerer, light!
Of all material beings, first and best."
THOMPSON.

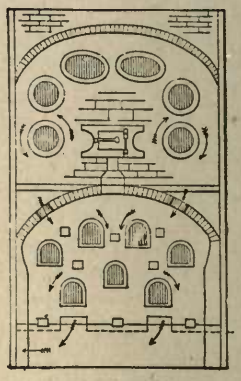
IF we could follow a very large quantity of coal to its destination we should find ourselves at the gas-works, where soon it is converted into its share of the million tons or more which we are told are annually needed to supply our great cities with light.

One ton of good coal, which represents, as we all know, 2,240 lbs., produces about one chaldron of coke, twelve gallons of tar, twelve gallons of ammoniacal liquor, a small loss (chiefly in water), and 9,500 cubic feet of gas, each cubic foot weighing 514½ grains. Now to see how all this is disposed of for the benefit of the public.

To begin with—The gas, or carburetted hydrogen, which is extracted from coal by distillation, leaves behind it that grey calcined substance well known as coke, some of which will most likely be used in the blast furnaces (it takes about 20 cwt. to make a ton of the best iron), the remainder being sold to various metal-workers, or broken up and burnt with coals in our own kitchen fires.

The large supply of coal to be dealt with, most likely either "caking" or "parrot" coal, is first placed in "retorts," or vessels lined with fireclay; they are some six or seven feet long, one and a half broad, and one high, and stand nearly five feet from the ground, being built in with firebricks. Several of these are arranged about and

arched over in such a way that they can be heated by a furnace below, the flames of which surround them all with an equally intense heat. We see a strange sight if we glance into one of these retorts, should it be opened to show the fierce glowing mass within. But as the supply of coal is put in, the mouth of each vessel is at once closed, screwed fast, and made air-tight with wet clay. Each retort has an iron tube projecting from this part of the oven; these tubes are intended to convey the steaming gases and matters into the "hydraulic main," a large horizontal iron pipe, half filled with water, into which all these smaller tubes pass and dip deep. This receiver is connected with the tar-well below, into which well all the tar and liquid ammonia that condenses from the hot gas will fall and settle. Owing to their greater gravity they can by means of a simple contrivance be drawn off, and after certain preparations take their various places in the world of commerce, as gas-tar, naphtha, ammonia, and other marketable things.



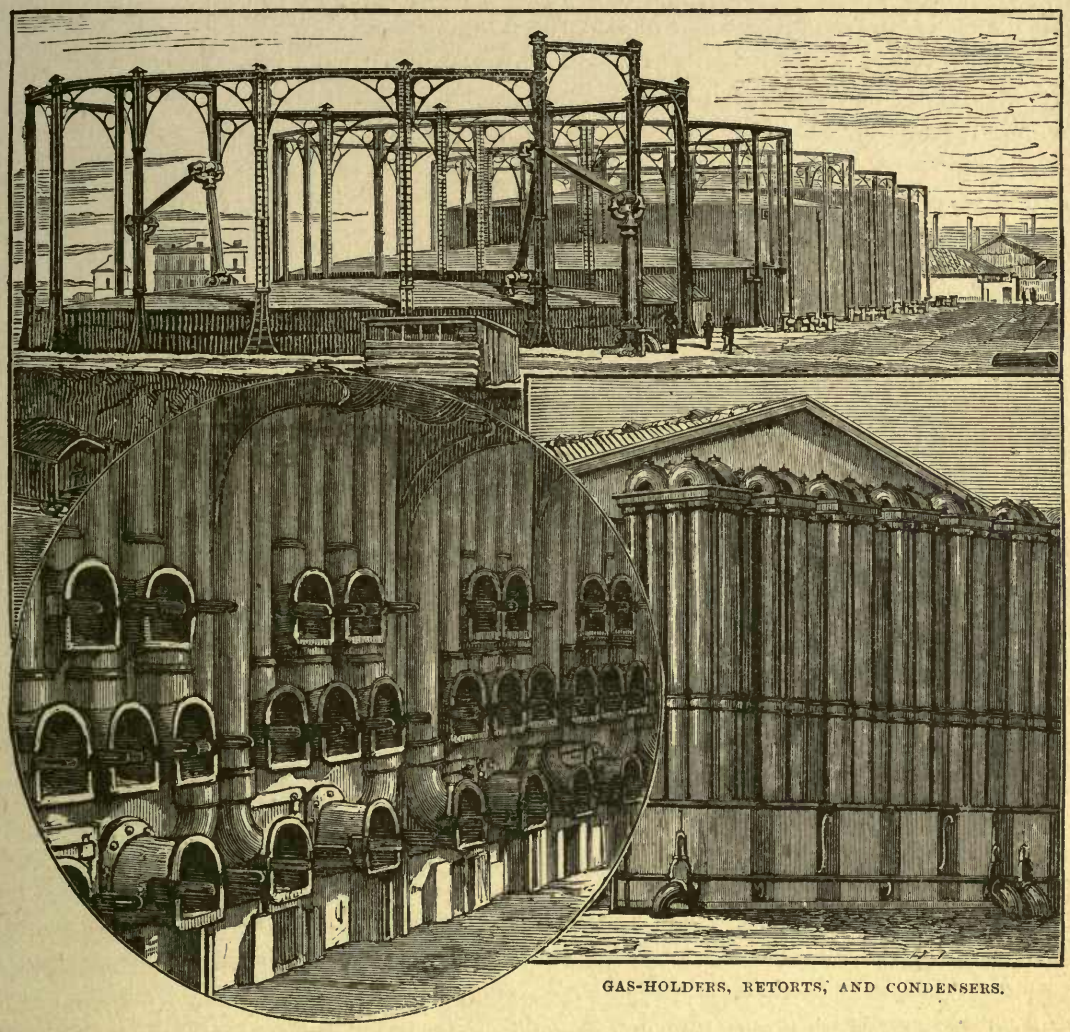
GAS-RETORTS.

For the present let us follow our coal-gas, which, being a gas, instead of descending into the tar-well, where it would be soon stopped by a dip pipe placed on guard, ascends and passes up into a curious contrivance called the "condenser." This consists of a series of curved upright pipes, joined at the top, and standing in pairs on a kind of large cistern, into which the ends of each pair communicate. From the centre of the bottom of each pipe a metal plate passes almost to the bottom of the cistern, and hinders the hot gas from at once passing through the cistern as it would naturally do. Finding no straightforward way, it rushes up the first pipe it meets with, then down the other side; then it goes flying up the next pipe and descends again, and so on until it has travelled through them all; and as they are kept very cold, either by means of air or cold water, the hot gas chills on its way, and this causes it to leave behind all the liquid vapours it brought with it from the retort. These, left to themselves, thicken and condense, and finally fall into the cistern below, from which they are passed, by means of a pipe, down to the tar-well, already containing other matters of their kind.

But there is yet another objectionable thing still clinging about and contaminating our gas; its name is "sulphuretted hydrogen." This has to be disposed of, as it is a most nauseous and unwholesome gas, and owes its existence to the iron pyrites, more or less of which is to be found in almost every kind of coal.

There are, I believe, two ways of purifying coal-gas, the usual one being to pass it into a broad perforated iron cylinder through a pipe which is lowered into an air-tight reservoir partly filled with lime and water kept well stirred by revolving metal arms. Into this "cream of lime" the gas passes from the holes in the cylinder, and as it leaves the mixture thousands of angry little bubbles rise as though in protest at such an intrusion; but this same lime, having an affinity for sulphur and other matters, attracts and retains the things which it is so desirable to get rid of, and the purified coal-gas rises lightly to the top of the reservoir, whence, having been measured by a "station-meter," it will be passed into the gasometer, where it remains prisoned until required. These huge gasometers —or gas-holders rather, for they do not measure gas—are usually to be seen in the

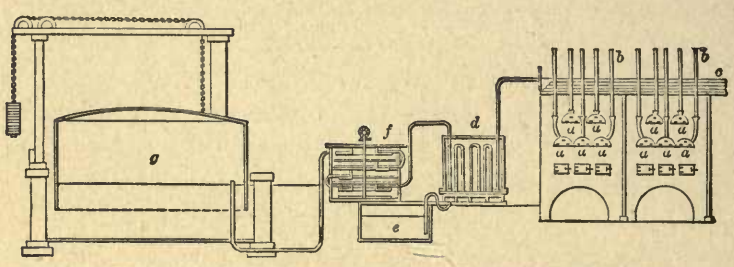
neighbourhood of railway-stations, where they are built for the convenience of storing coal. You will see their peculiar shape by referring to the frontispiece of this volume. Ingenious constructions, and well worthy of notice, they are made of iron plates firmly riveted together, and are in the form of two monster metal tumblers — one



GAS-HOLDERS, RETORTS, AND CONDENSERS.

always slightly smaller and fitting into the other; the larger or under one being merely a round open tank, of cast iron, stone, or brick, lined with fireclay, and nearly filled with water. From the bottom of this tank a pipe ascends, intended to admit the gas into the empty space left above the surface of this water; and the upper half of the gas-holder, which dips into the lower half so as to cut off all external air passing into the upper half, holds the gas, which it presses down and so squeezes through the main pipe, which also descends through the water, placed there to retain the gas in the vessel. When the gasometer is quite down, we may conclude it is empty, the inside of its top resting on the water with which the under half is, we know, filled. As the new-made

gas enters, we may observe the huge top half, which is held and suspended by chains and weights that allow of its moving freely, gently rising; and, watching it until it is full, we shall presently see its entire shape, only its lower rim or edge is not to be seen, as it rests a few inches below in the water, where it is held by the shape of its frame, which, expanding at the edge, keeps it from ascending above the water in the tank, and allows no escape of the gas within. When night comes on, and some of the contents of the gas-holder is required, the upper half is slowly worked down again by means of its own weight, and this as it descends presses on the gas between it and the water, forcing it through the tube and into the main pipe, which will soon send it streaming in every direction; for we know how everybody rushes at once to "light the gas," wasting few thoughts upon what a wonderful slave it is—ready at one instantaneous touch of fire to spring into visible existence, and beam on streets, shops, theatres, churches, conveying light and comfort into our drawing-room, or heating a stove in our kitchen.



a, Furnaces and Retorts; *b*, Branch Pipe connecting with Main; *c*, Main: *d*, Condenser; *e*, Washer; *f*, Purifier; *g*, Gas-holder.

This is a very trying time for the attendants of the big gasometer, as great care and attention are required to supply the sudden demand for light; the gas has to be evenly distributed at the farthest point to which the service-pipes stretch, as to the nearest street. To do this, the gas stored in these big cylinders must receive a certain "pressure," no more or less, to judge of which requires experience and care.

Inquiring into the history of coal-gas, we find it first mentioned about two hundred years ago as a strange curiosity, which was chanced upon by Robert Clayton, Bishop of Cork, who, it appears, first distilled a few coals, and obtained gas from them. He wrote: "I kept this spirit [gas] in bladders, and when I had a mind to divert strangers or friends, I have frequently taken one of these, pricked a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it once took fire, it would then continue flaming until all the spirit was compressed out of the bladder, which was the more surprising because no one could discern any difference in appearance between these bladders and those filled with common air." No doubt the good Bishop's strange experiment was much talked about and puzzled over at the time, but though it was communicated to the "Royal Society" as worthy that august body's notice, we do not hear that any particular effort was made to forward the discovery as a matter of general importance, though later on some few believed in the possibility of illumining houses, if not streets or towns, with this new light. Others laughed at and ridiculed the very notion; many learned and scientific men opposed it, even were it practicable, on the ground of the danger and expense such an unlikely method of obtaining light must involve. Yet they were all in

the wrong, as modern experience has proved in the most satisfactory manner that as yet, at any rate, whatever follows, gas has so far provided the cheapest and safest illumination.

Nearly the first authentic notice we have of the gas of pit-coal being practically applied for lighting is in connection with William Murdoch, engineer to the celebrated firm of Boulton and Watt, of Old Soho. He was a clever and ingenious man, about whom I must tell an interesting anecdote.

One day a poorly-attired young Scotchman applied at the Old Soho Foundry for work. He chanced to be shown into the office of one of the heads of the firm, who was a shrewd observer of character, and so thorough a man of business, that Boswell styled him an "iron king." A shabby young Scotchman in search of a situation was no uncommon visitor at the foundry in Birmingham, and as there chanced to be small need for the stray services of inexperienced youths, this one was very soon summarily dismissed.

"No vacancy, young man"—words soon said; but though spoken in kindly tones, they fell on the shabby stranger's heart like lead. He and his were *so* poor, and had been *so* hopeful, and he had made such efforts to get at Mr. Boulton, all for nothing. The busy head of the firm had scarcely even looked at him, only flung those hard words over his shoulder, "No vacancy." The young fellow, loth to accept the verdict, stood nervously twiddling his hat for such a long time, that Mr. Boulton at last turned impatiently to survey the troublesome petitioner, perhaps to give him a more decided dismissal. At any rate, he turned and fixed his eyes inquiringly, not on the youth's disconsolate face, but upon the hat he was all unconsciously twiddling about and smoothing every way with his red and awkward fingers.

What a hat it was! smooth and hard and black and as round as a metal pipe. People in those days wore beaver, and there was not the same variety of head-gear as now, or perhaps Mr. Matthew Boulton might not have been so struck by this one as to inquire what it was made of, instead of repeating his last unwelcome remark, even holding out his hand for the peculiar article that had so suddenly excited his wonderment. We can fancy how that bashful Scotch lad blushed up to the roots of his hair, partly with mortified pride, partly with honest satisfaction at the evident interest taken in his work by this great "iron king," for the hat really was his work—his very own; made of wood and turned in a lathe, because he could not afford to buy anything new of the kind, and he had been told he ought to wear a "top" hat, not a cloth "bonnet," when he came to ask for a situation at the big forge. Not that he had ever seen or heard of a wooden hat before, but he had nothing but wood to make one of. Yes, it had been rather difficult to turn in a lathe, he allowed; besides, before he could make the hat he had to make a lathe. No one showed him how to do that, but he had managed it somehow; the lathe worked pretty well, he thought, though he meant to improve it yet. Mr. Boulton listened patiently to the lad's simple history of the ugly black hat and the lathe, to him a record of difficulties overcome by patience and ingenuity; then, instead of repeating "No vacancy," he engaged the overjoyed youth to fill some lowly position where he could earn a whole seventeen shillings a week. The shrewd "iron king" had made no mistake; the ingenious head and the ready hand were there, suited, as he thought, for greater tasks; for we next hear of this same young William being engaged in fitting and rectifying the large engines for which

"Old Soho" was famous. The day came when his kindly master could say, "We want more Murdochs." It was this same William Murdoch, by that time holding a good position in the firm, who, in 1792, first thought of utilising pit-coal for the lighting of his house and offices at Redruth, in Cornwall. He made plenty of experiments, no doubt, before he was able to imprison its gases in a gasometer, from which he carried pipes to the different apartments, tubes with holes in them that could be opened or closed at will.

As to the ammoniacal liquid which is one of the results of gas-making, we meet it first being emptied by large barge-loads into the iron tanks of chemical works. It is then put in vessels, where by means of heat it is volatilised, and passing through large "worms," condenses in the cistern in which it is received. It is next treated with hydrochloric acid, and the solution thus obtained passed on to iron pans, in which it slowly boils until it is ready to crystallise; then it is run into coolers, where it ultimately forms into crystals of crude salt of ammonia, which is afterwards refined by a variety of processes, the most important of which is "sublimation," to effect which the salt is slowly dried, and then placed in iron vessels with dome-like covers. As the heat reaches it, the salt volatilises and rises in the cover, gradually encrusting it with crystals of sal-ammoniac, which can be removed in a cake and broken up as required by the various workers who use it, especially galvanisers of iron, and tin-plate workers. A great quantity, we are told, is exported to Russia, where it is used by the peasants instead of common salt.

One other use this extract of coal has, which you will never guess at, unless to help your fancy you sniff at a bottle of strong smelling-salts, and then you have it in the shape of carbonate of ammonia. A great quantity is also used in dye-works, ammonia having a peculiar effect upon vegetable colours. Not only is it useful in itself, but our health as well as busy commerce would flourish badly without it. A small portion is in the air we breathe and in the rain-water that falls about us—in fact, life could scarcely exist in its absence. Of course it was known long ages before gas was heard of. Its very name is said to be derived from its manufacture in a district in Lybia where Jupiter Ammon was worshipped. In those days it was procured by heating animal refuse, though it was also obtained from the distillation of deer's horns, reminding one of that pungent preparation of it still known as spirits of hartshorn.

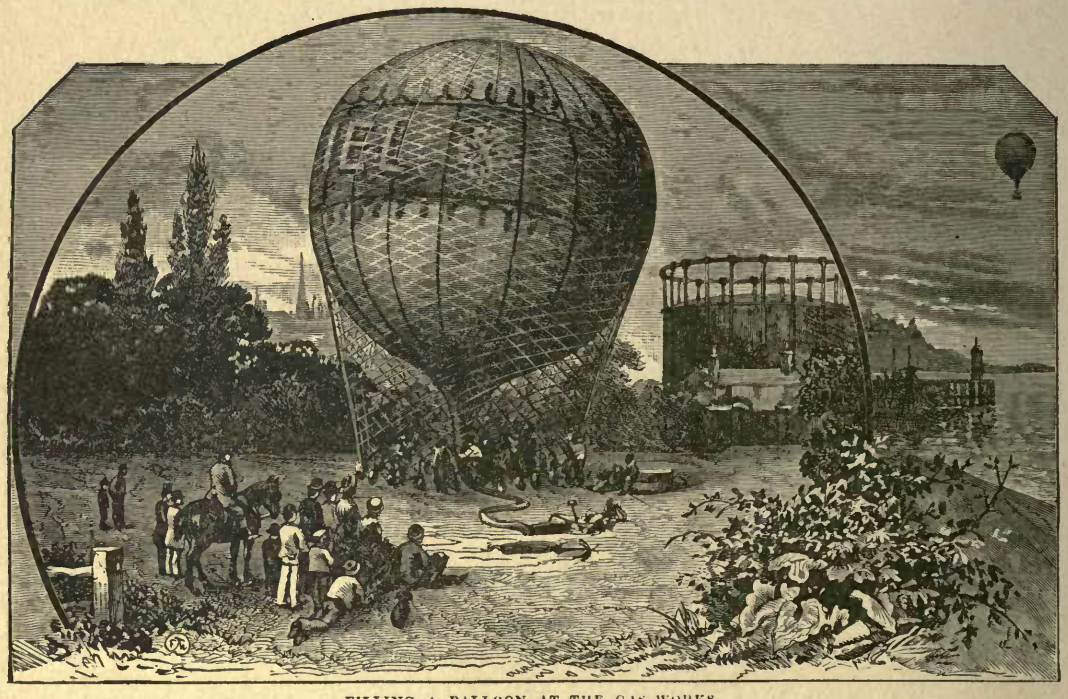
Now that we have seen how from our ton of coals we get coke, gas, and ammonia, let us inquire what has become of the ten gallons of tar which have to be accounted for. If we ask of some skilful chemist the nature and uses of this unpromising-looking mess, he will most likely tell us that it is "a highly complex mixture of various compounds of carbon and hydrogen." Very true, no doubt, but this does not explain to us what we want to know—namely, what place does it fill in our Wonderland, where coal and its other constituents hold such important positions that each is worth realising? Strange to say, at a not very distant time it had no place worth mentioning. This unavoidable residue of strong-smelling, treacly coal-tar was looked upon by all owners of gas-works as mere noxious refuse they would be glad to get rid of on any terms. Yet now this hitherto objectionable "waste" is proved to be very valuable. Carefully analysed, it has already produced over fifty distinct and useful things. Among the most important of these we may reckon "benzol," from which, by further treatment, are obtained

brilliant crystals which yield the aniline dyes so useful to our several workers, and concerning which we shall have more to learn presently. Its uses, when in quite a crude state, we are most of us well aware of, for we have both seen and smelt it on boats, wooden walls, and palings, when on our country walks. Touched by the same chemist's wand, it is transformed, and the sticky black-brown mass is dissolved into various things, such as naphtha, heavy or creosote oil which serves for the preservation of railway sleepers; and ordinary pitch, the appearance and smell of which most townspeople have become well acquainted with through the asphalte pavements and roofings, and which we can find by tubfuls in any shipbuilder's yards, where timbers and ropes seem alike saturated with this black and sticky mess used to make them waterproof.

Naphtha, which has several names, has also many uses in our Wonderland. Besides furnishing its workers with a pure, clear light, it acts as a solvent for fatty or resinous substances, as also sulphur and phosphorus. Chemists use it for the preservation of certain metals and other substances; but it is especially of service in the manufacture of india-rubber and gutta-percha—two articles now of the greatest importance in commerce, for of them are made numberless objects, from a baby's teething-pad to the coating of the Atlantic cable, from a coat or a bed to an elastic band to fit our finger. Then comes paraffin, another production of coal-tar; its curious name is made up from Latin words which signify that it has little or no affinity for other substances. Its discovery was singular, and we owe it, as well as many other things, to "a man with eyes," who one day, peering about in a coal-mine at Alfreton, in Derbyshire, chanced to notice that a thick, oily-looking fluid was dribbling from the cracks in the roof. The attention of a skilful chemist having been drawn to this strange substance, he distilled two useful things from it—the first a light oil fit for burning in lamps; the second a thicker, coarser oil suitable for lubricating machinery. Both of these found a ready sale, yet after a time the original supply began to run short. Fortunately thinkers had come to the conclusion that this paraffin was produced through the distillation of coal by subterranean heat; natural process was imitated, and large quantities of the same kind of liquid easily made.

One curious sight we chance upon in the neighbourhood of these massive-looking gas-holders—that is the filling or inflating of a great baggy mass of soft materials which are gradually assuming the graceful form of a balloon intended to ascend this afternoon. We are told that, to save the trouble and expense of making pure hydrogen gas for the purpose, as once had to be always done, our aeronauts are very glad, when it can possibly be managed, to obtain the large supply of gas they require from the nearest gasometer, from whence it is conveyed by means of long tubes, which pass straight from it to the mouth or neck of the balloon. If we examine the as yet half-prostrate object, we can see that it is fashioned out of long strips of stuff, which are sewn strongly together, and then made air-tight by means of a coating of caoutchouc. A valve is fitted to the top or roof of the contrivance, worked by aid of a spring, having a long rope which reaches to the car, by means of which valve the aeronaut can lower his balloon by letting off some of the gas, which is now slowly but surely distending its huge round body, and displaying its showy colours and inscription, as well as stretching the strong rope network which covers it all over and supports the car which is to carry both passengers and ballast—that is, the sacks

of sand, quantities of which will be thrown overboard should this strange vessel be in danger of touching anything, or seem likely to land in any undesirable or dangerous place. As the silken globe begins to fill with gassy life it shows symptoms of an inclination to be off on its travels; but it is held fast enough as yet by many ropes, and we cannot help noticing what a very different thing a balloon down here is, to what it appears to be when it is sailing far overhead, sometimes such a mere speck in the horizon that we scarcely see it; yet an ordinary balloon with power to carry three of us up into cloudland, with all the ballast and other things required for our "sky" journey, would weigh, silken skin, stout network, and car, somewhere about 330 lbs. It would be almost fifty feet high,

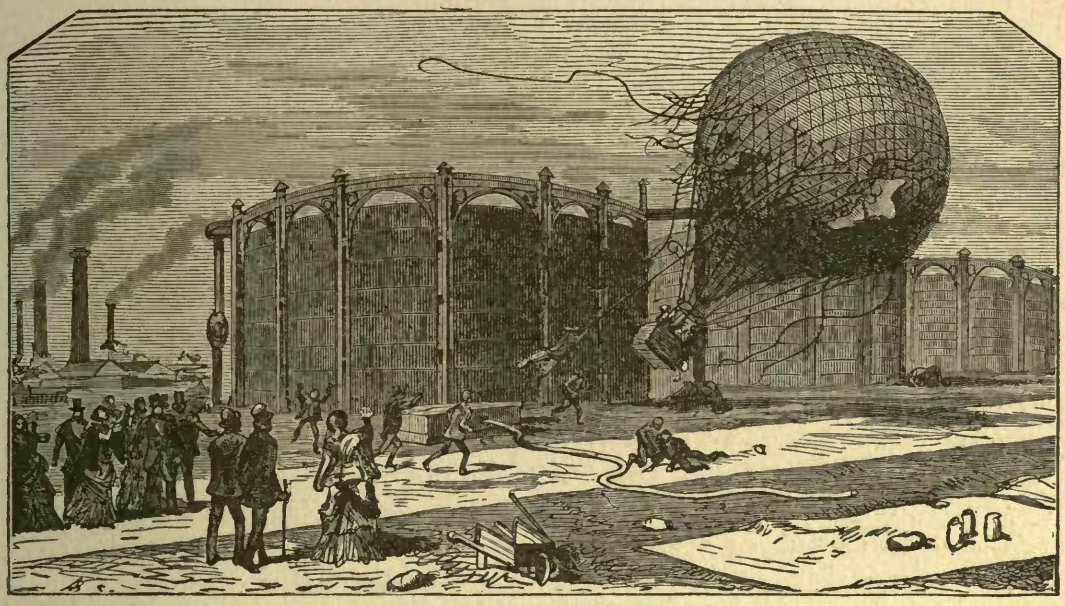


FILLING A BALLOON AT THE GAS-WORKS.

thirty-five in diameter, and contain about 2,250 cubic feet in capacity, though we are informed that it is purposely never quite filled, because the atmospheric pressure, diminishing as it ascends, allows the gas to dilate, and unless there were room for this to expand the whole contrivance must burst, and death and desolation ensue. Such an accident has been known to happen even before the balloon was fairly started and clear of the gas-holder. We can fancy the consternation of the onlookers at such a catastrophe.

Just about a hundred years ago the first gas balloon ascended in Paris. Hydrogen gas, or, as it was then termed, "inflammable air," had lately been discovered by Cavendish, but its powers were scarcely realised, when a Dr. Charles applied it to inflating balloons, believing it to be much lighter than the hot air that had hitherto been tried. Finding his first experiments successful, he at once set to work to construct a larger balloon of taffeta. From what we read, the inflation of that mysterious balloon must have been a most exciting affair, very different to the matter-of-fact business we are watching here to-day,

under the shadow of the huge gasometer so silently doing its work. First the gas had to be provided, and the supply of hydrogen was no small or inexpensive matter—1,125 lbs. of iron and 560 lbs. of sulphuric acid being found necessary to compose the gas required to inflate this wonderful object, which after all could scarcely lift a weight of 22 lbs. The hydrogen, let me here mention, was produced by placing water and some sulphuric acid, shavings of iron, and zinc in different casks, which all communicated by means of tubes with a central cask, the open end of which rested in a copper pan full of water; the required gas being produced by the action of the water and sulphuric acid upon the zinc and iron, which gas in passing through the central vessel full of water would throw off all extraneous matter, and be quite pure when it passed into the balloon by means of a tube from the vat.



THE ESCAPE OF A BALLOON.

When the partial filling of the balloon had been achieved—a process which took over four hours—it was carried to its starting-point in triumph, fastened on a cart, the greatest anxiety being lest the gas with which it had been charged should escape on the way. It was removed at night, preceded by a torchlight procession, and followed by an armed and mounted patrol to keep off the thronging crowd. Once safe at its journey's end, it was fixed and held fast by strong cords, chains, and iron rings set deep in the ground; then, in the presence of many scientific men, a final inflation took place amid the wondering stare of thousands of people, kept in order by troops, who guarded the avenue on all sides. All being ready, a cannon gave the signal, the restraining cords were unfastened, and, to the delight and wonderment of the assembly, off shot the balloon right up and away into the skies, followed, we can fancy, by a long irrepressible cheer from the multitudes present. Up and up it sailed, soon to be lost in a cloud, then re-appearing, to be missed in still higher space. Never surely has balloon caused such excitement from first to last; yet it was a mere baby to the one now before us, being only twelve

feet in diameter, thirty-eight feet round, and capable of containing 943 cubic feet of gas. The weight of the whole concern was but 25 lbs. In these days we should consider it a mere toy.

In a very short time this admired silken marvel had sailed out of sight of any amount of staring. It travelled away bravely until it came to the open country far beyond Paris, where some peasants were busy at their harvest work; and here, because of the expansion of the gas, with which it had been too thoroughly filled, the wonderful thing suddenly burst, and dropped shattered and "dead" on the ground—a natural enough sequence. Yet who can paint the horror and affright of these superstitious peasants when this fearful thing from the skies fell among them? What they took it for I do not know; but some shrieked and fled for dear life; others ran at the enemy with flails, stones, and pitchforks, and beat, mauled, and hammered at the poor thing, especially when they found it did not resist their onslaught. At last they tied it to a horse's tail and dragged it about in the mud; so that when the disappointing and disheartening news of its accident reached Paris, and search was made for its remains, only a few torn fragments could be discovered. And the peasants boasted loudly of their courage in destroying it.

As nothing more could be done in this sad case, the Government published a long paper for the benefit of ignorant country folks, solemnly warning them against "kidnapping air balloons," and bidding them not to be again afraid of any "black moons" they might see in the sky, as they would only be silken bags filled with gas, and quite harmless. But as this first attempt served to show that gas would carry up balloons, other "moons" were therefore soon fashioned, some of which were great advances on the first one; yet it was some time before any one dreamed of risking his life by going up with such a thing. The first experiment of the kind was tried upon a sheep and some pigeons, which were safely carried about 1,700 feet, being secured in a dangling osier cage. The poor things must have felt some uneasiness at their strange heavenward journey.

If you ask, as did the people of those days, why does gas poured and fastened tight in this silken bag carry it up skywards where nothing else would take it, I must answer by quoting a certain ancient principle of Archimedes, which states that "every body plunged into a liquid loses a portion of its weight equal to the weight of the fluid it displaces." Thus, a body plunged into water is acted upon by two forces—its own weight, which would sink it, and a resistance, which bears it up. This applies to air as well as water, to gas as well as to liquids. Any object weighed in the air does not now weigh its own weight, but that weight minus the air its presence displaces. If that same object, being heavier than the air it displaces, be thrown into the air, it falls at once. If it is of equal weight it simply floats, but if lighter it rises until it meets air of less density than itself. Balloons, being light air-tight material filled with hot gas, rise because they are lighter than the air they displace.

It is night when we leave the huge gasometer, and as we pass through noisy crowded streets, full of light and life and business, we cannot help considering what a dreary change it would be if we had to submit to the lighting arrangements of a few centuries ago, for in those days, or rather nights, the streets of cities were illumined only by a few straggling horn lanterns, which the principal householders were obliged to hang before their

doors; warned to this duty by ancient watchmen, who trotted round the parishes, stopping before doors and calling out, "Lanthorne and a whole candell light! Hange out youre lights heare!" which the grudging citizen must unwillingly do, or be fined. But the spare rush "candells" gave a poor unsteady light at their best, and usually had all flickered out in a short time. The darkness that ensued allowed of so much licence and disturbance that it was considered a very great advance when a few oil-lamps gradually begun to twinkle here and there. These were at last adopted in all the leading thoroughfares of great towns, while instead of the expense falling on private persons continually grumbling at this grievance, it was defrayed by a regular lighting-rate, levied on all houses.

THE UNEXPECTED DESCENT OF THE FIRST BALLOON.

The establishment of single watchmen, one of whose duties it was to call out the hours, was at one time general in London, and took its rise in Germany. Montaigne, in 1580, wrote that—"The watchmen went about the houses in the night-time, not so much on account of thieves as on account of fires and other alarms. When the clocks struck, the one was obliged to call out aloud to the other, and to ask what it was o'clock, and then to wish him a good-night." Previously to these watchmen who patrolled the streets, men were stationed on steeples by day as well as by night, who, every time the clock struck, were obliged to give a proof of their vigilance by blowing a horn. The Chinese are said to have been accustomed, as early as the ninth century, to have men posted on towers, who announced the hours of the day and night by striking upon a suspended board. In St. Petersburg men were formerly stationed in various parts of the city to tell the hours by beating on iron plates.

English street-lamps were in time improved. At first they swung on ropes or rough wooden beams, but later those in our grander streets were fixed to iron lamp-posts made for the purpose, whilst those in some of the doors of the houses in the "West End"

squares had often very elaborate workmanship of wrought-iron about them. At many of the gates of the most aristocratic old mansions we can still see the large trumpet-like extinguisher, placed handy for the extinction of torches, which were carried on a dark night by footmen standing behind carriages, and flourished as a kind of protection against any evil-doers who might be abroad annoying ordinary wayfarers, but quiet when

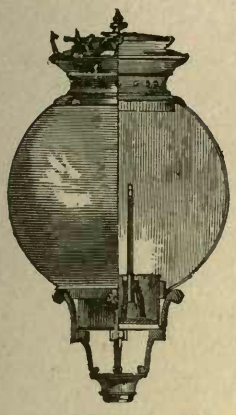
"Afar they mark the flambeau's bright approach,
And shun the shining train and golden coach."

Some of these solemn old neighbourhoods were for long in semi-darkness, for their noble inhabitants declined to avail themselves of the benefit of gaslight while they could enjoy the sober advantage of watching the dismal oil-lamps of their predecessors, and be nightly roused by the rattle or the cracked voice of some passing watchman, who continually disturbed their rest to tell them "what's o'clock." Yet it must have been rather a selfish pleasure for those snug in bed to hear a doleful announcement outside of "past two, and a windy morning." Gas only stole into Grosvenor Square in 1842, though Pall Mall had set the example as far back as 1807, shortly after which the citizens ventured upon lighting up Bishopsgate Street in the same manner, in spite of repeated warnings as to the fearful consequences which must ensue; for many believed and feared that when a number of gas-fires were lighted, those stray folks who were not poisoned by the noxious vapours must all be blown up by the many explosions sure to follow in every direction.

But there is another sort of light now rapidly gaining ground, and which is produced by the aid of electricity. It is especially adapted for large buildings, lighthouses, docks, ships, and open spaces which require thorough illumination—such as the broad Thames Embankment in London, the new Albert Docks, where Siemen's lamp lights up their miles of wharves and quays, and the Place de l'Opera in Paris, where it can be seen to perfection, producing a kind of artificial daylight of the most brilliant kind, and before which ordinary gas pales to insignificance.

The apparatus used consists of a machine for generating an electric current, lamps for regulating the light, and carbon points, or wicks, which are heated to a white heat by the passage of the current, or yield a bright electric "arc." A system so far much used in London is the Jablochkoff "candle," which consists of two sticks of carbon placed side by side, a stick of pure kaolin, or china-clay, intervening. The current is arranged to flow up one stick and down the other; in doing this it is obstructed by the kaolin, which will not conduct the electric fluid, and which is merely to keep a regular distance between the carbons, wasting away as these are consumed, so that the whole candle burns down together.

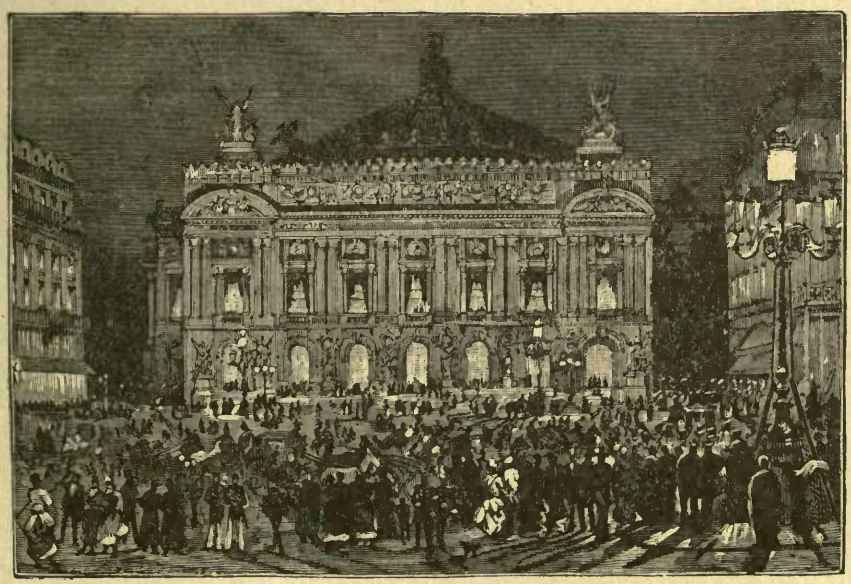
Here you see the "candle" in a glass globe; and also an enlarged view of the two carbon sticks with the china-clay between them. The current is usually supplied by what is called a dynamo-electric machine worked by a steam or gas engine, so that gas is used even under this new system.



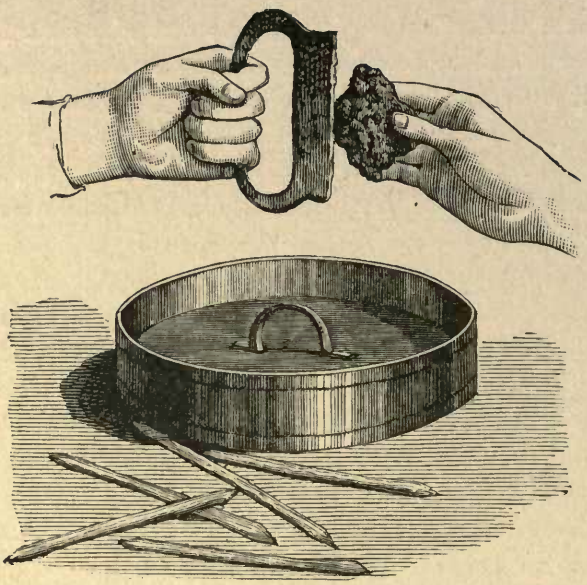
JABLOCHKOFF LAMP.

TOP OF JABLOCHKOFF CANDLE (ENLARGED).

There is another method of producing the electric light besides that of the bright electric arc, known as the method of "incandescence." In simple words, if a powerful current is sent through an imperfect or too small conductor, it makes it glowing hot. Platinum wires are sometimes used; but the best lamps of this kind have been made of very small slips of carbon, which have to be enclosed in globes emptied of air, in order that they may only glow with the heat and not burn away. This kind of light is much less and of a softer kind than the other, and it is hoped that ere long it may be successfully introduced, even into private houses. But exactly the best system has yet to be determined, so many points having to be considered before deciding the question, and improvements are made in one point or another almost every day. Six different systems of electric lighting have recently been tried upon a large scale in the streets of London alone.

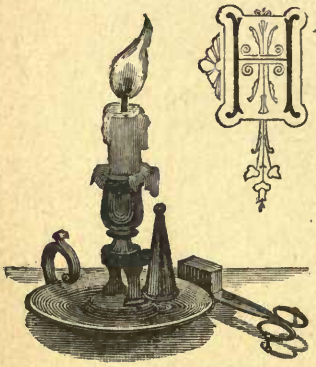


PLACE DE L'OPERA, PARIS, ILLUMINATED WITH THE ELECTRIC LIGHT.



TINDER-BOX, FLINT, STEEL, AND BRIMSTONE MATCHES.

STRIKING A LIGHT.



THE TALLOW CANDLE.

HAVING said so much about coal, gas, and the troubles of our forefathers concerning fuel and light, let us spare a little time to learn something of a humble but very useful article, the history of which is worth mention here. I mean the lucifer match of every-day life. In our grandfathers' time there were no such things as these handy little servants, or at least they were only beginning to be thought of. People used a clumsy contrivance known as a tinder-box, over which they wasted a great deal of time and patience, until presently chemistry came to the rescue in this, as in greater things, and then succeeded the manufacture of instantaneous light—at first by means of small metal bottles containing phosphorus, stirred about with a red-hot wire, or with a combination of fine cork, petroleum-wax, and phosphorus. These much-vaunted "Briquets Phosphoriques" cost seven-and-sixpence each, and were only supplied with one dozen matches or splints, which had afterwards to be bought separately in little threepenny bundles (your grandmothers well remember such things, I do not doubt). Into these bottles the small splints of wood tipped with sulphur were dipped, and when withdrawn ignited silently through the chemical action of the air. This was justly considered an immense advance upon the noisy flint and tinder business, even though they were very expensive, and so much patronised by rogues that they obtained the name of "thieves' matches."

Very many new inventions followed, one of the best and cheapest being, I think, a box which could be purchased for a shilling. It was divided into two parts—one containing matches dipped in a composition of sugar and chlorate of potash, while the other held

asbestos soaked in oil of vitriol. The match on being dipped into this burst into a bright flame—that is, if it were perfectly dry and in good condition, otherwise it was useless.

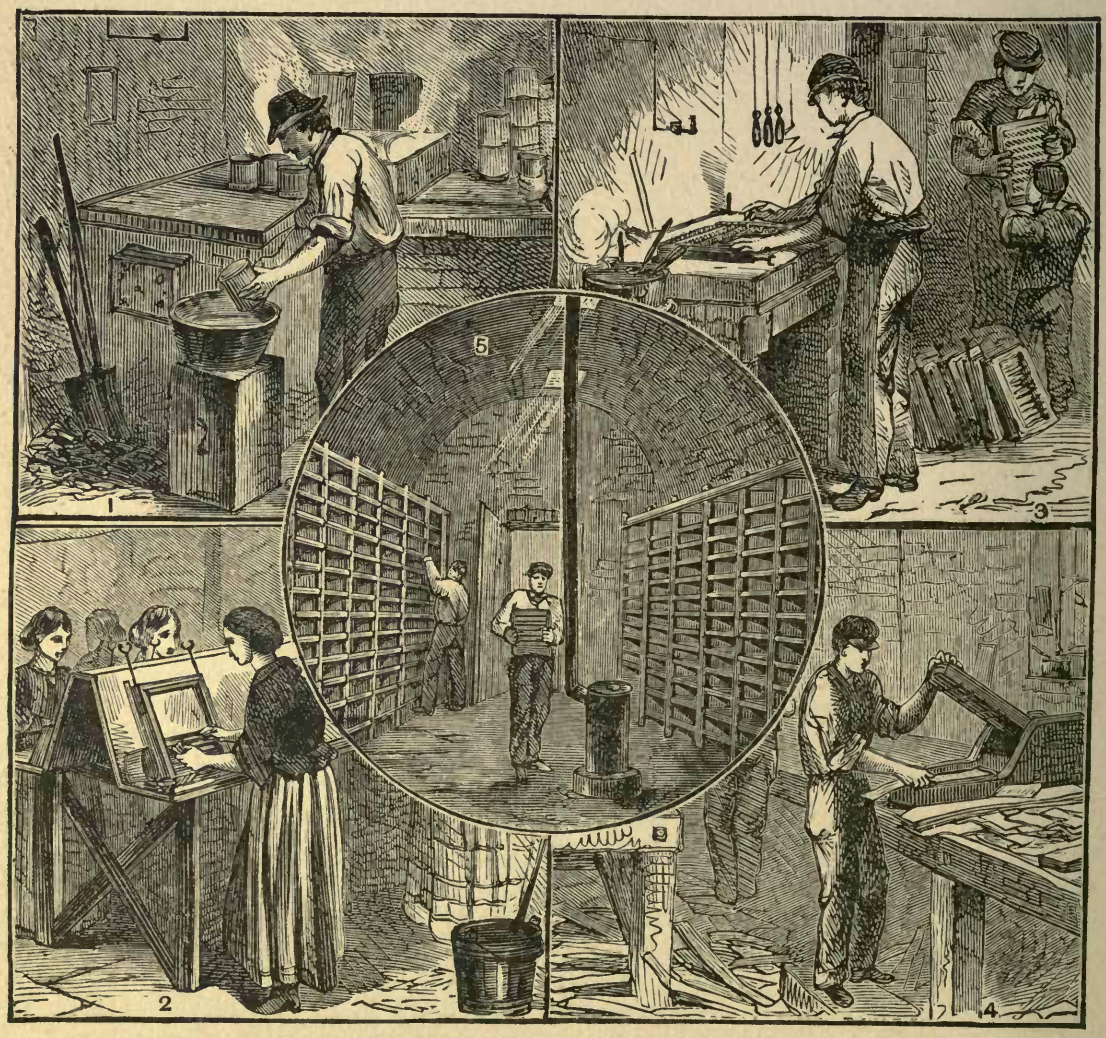
It was not until 1826 that matches to light of their own accord were manufactured, but it was ten more years before lucifer matches, as we know them, appeared in the market, certainly excelling all that had gone before, though for a long time the public refused to patronise them, disliking the strong smell of the phosphorus, and concluding blindly that the whole thing must be as dangerous as it was certainly disagreeable. For a long time after lucifer matches had become popular and in general use, they were but comparatively little made in England, where, in consequence of the combustibility of the materials then employed, a match-factory had to be built at least fifty feet away from all habitations; besides this, English matches as a rule were as yet of a very poor and uncertain quality. No wonder that the dealers looked for their supply to Vienna and Bohemia, but more particularly from Sweden, then the great market for this useful little article. This is what was written on the subject only a few years ago:—

"We must render due homage to the industry of the Swedes, who for many years have supplied all Europe with matches. To them is due the earliest practical application and introduction of the patent safety match, which at first the facetious somewhat unjustly described as warranted to 'light only on the box, and very seldom there.' Formerly the town of Jonkoping, in Sweden, enjoyed the monopoly of manufacturing safety matches for the whole Continent, but now the inhabitants of several other towns have started the same industry, and foreign countries also hope to compete with this trade. But the demand for Swedish matches, nevertheless, constantly increases, and some difficulty is experienced in procuring a sufficient supply. A glance at the export returns for the year 1873 establishes conclusively the importance of this trade. It appears from these documents that Sweden sent abroad no less than 8,351,028 lbs. of matches in that one year, and that out of this number no less than 4,490,024 lbs. came to England. From these facts curious statistics may be readily worked out, for we can reckon that each box weighs one ounce and contains a hundred matches. Thus we have a total export from Sweden of 13,361,644,800 matches, out of which we burn 7,184,038,400 in England. But the calculation goes a step further. Dividing this figure by 32,000,000, the rough estimate of our population, we discover that on an average every inhabitant of England consumed during the year 1873 a total of 225 Swedish matches." But now matches noisy and matches silent are alike manufactured in England—matches no longer sputtering out while choking us with their objectionable sulphurous fumes, but lighting quietly and at a touch.

Stepping into one of these English "match-maker's" establishments, you would be quite surprised to see what a large place it is, and what a number of hands are employed in the manufacture of what we may have been accustomed to consider a very insignificant thing. A penny box of these tiny splints lying so snugly one on another serves the requirements of a whole household for several days, yet we find whole shiploads of the best Quebec pine are constantly imported for the special purpose of being used by this one firm. The logs are sawn up into "deals," the best and straightest of which are selected to form the matches, the rest to make the innumerable boxes required to contain them. All the rough remainders will serve for the large packing-cases into which those thousand

dozens of small boxes will be packed and sent on their travels. It is evident that very little of that huge pile of wood will be wasted in our Wonderland.

The first set of deals have been carried into a shed and roughly planed before being cut into little blocks and splints of the precise length of two matches in one. This is done by means of knives acting in a "block" machine, in which a row of blocks are



MANUFACTURE OF LUCIFER MATCHES.

1. Scorching.
2. Filling Frames.
3. Dipping.
4. Stamping Boxes.
5. Drying Room.

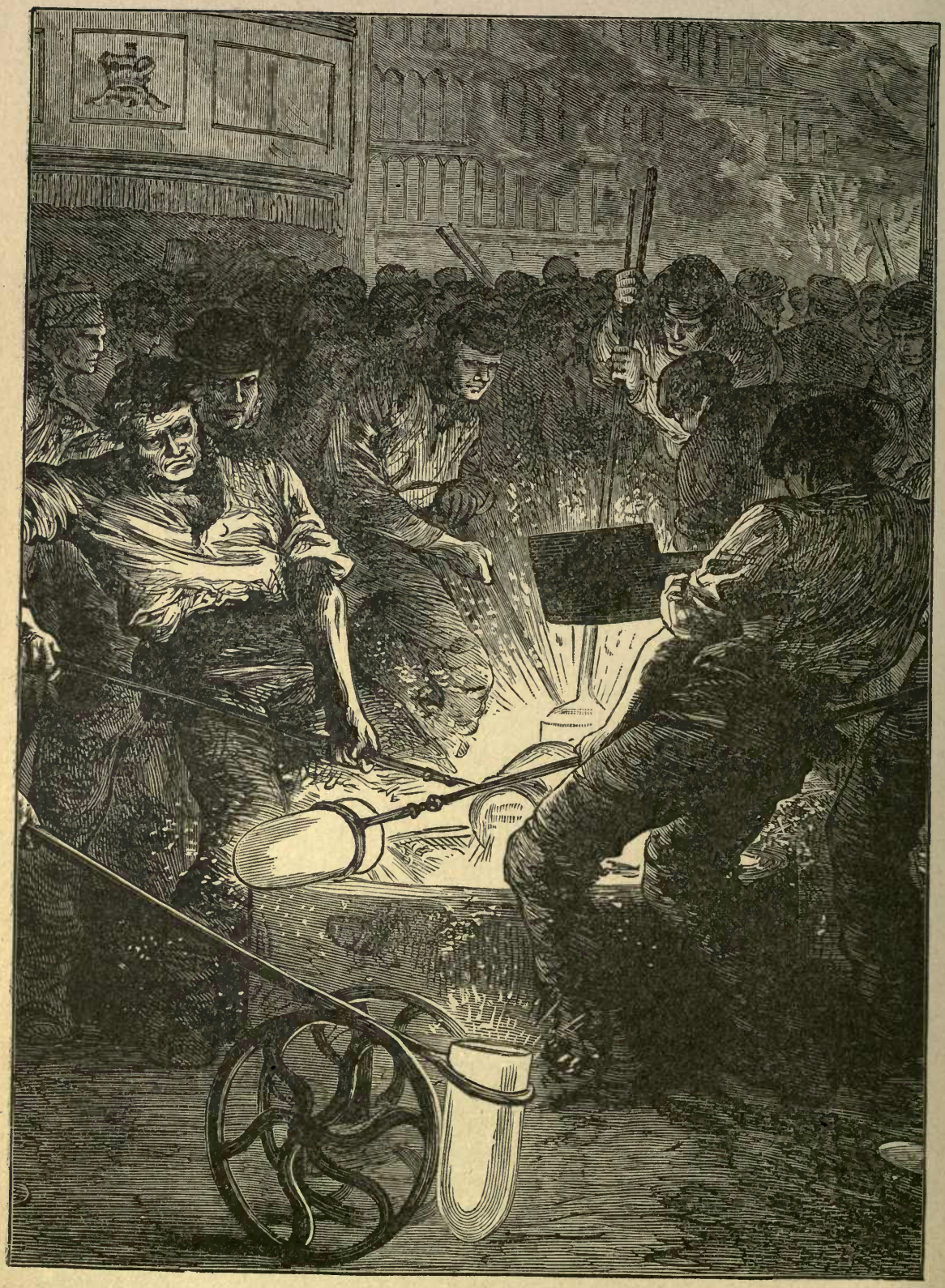
placed, and passed across a row of sharp blades that cut their way in; then as they return they meet other oddly-shaped sharp knives that again cut them the contrary cross-cut direction, so that the bits fall in a light shower of tiny sticks, which are quickly gathered clear out of the way and placed in metal rings, which will be ready for dipping when filled and screwed tightly together. As I describe it, it sounds as though it might be a slow process, but at any rate the worker tells us this machine

cuts 15,616 double splints, that is, twice as many matches, every minute we stand watching it snapping at the blocks, which drop before it as though by magic.

If they are to figure as paraffin matches (the old sulphur abominations have well-nigh vanished) they will be taken into a room where each bundle of splints must be held endways, for an instant, on a plate of hot iron, so that they get slightly scorched and very hot; then a boy passes them on through an opening to a worker in the room, which is quite handy, and here each end of every scorched bundle is dipped into a flat pan or perhaps held against a piece of thick felt soaked in melted paraffin, of which the hot wood soon absorbs a sufficient quantity, after which the bundles are ready to be put into a large circular frame, and to be snipped into halves or separate matches by a circular saw which Giant Steam keeps going steadily all day long.

It used to be the custom to dip the bundles as they were into the composition, whatever it was; but that was found to be but an awkward method, as the matches often stuck together when drying, and burst into flame when dragged apart; so now they are framed, and dipped separately by means of an ingenious machine well worth noting. First we see the scraps of wood dropped into a kind of hopper, which being in a state of constant and steady "hop" soon shakes them out again, to be pushed forward into the frame. A lath is put between each row of splints. When about 6,000 of these are in place they are screwed tightly down, and sent off to the "dipping arcade," a long, airy, clean room where no whiff of sulphur comes to remind us unpleasantly that lucifer matches are being dipped all about us. Here a large crowd of girls are busy popping the ends of the bits of wood into a pasty composition of many colours, which is spread thinly on great stone slabs before them like some kind of butter of a ruby or ultramarine colour, kept warm and moist by hot-water arrangements below. What this bright mixture or mixtures may be, for they vary somewhat, we need not inquire, as it is a trade secret and does not concern us much. The frames, with their "dipped" contents hanging head downwards, are all carried off to the fireproof drying-room, which is well carpeted with thick layers of sawdust, which we are told is very useful in cases of fire, that will "try" to happen sometimes in such a place as this, but is usually so closely watched for that it has no chance. When all these "dippings" are dry they are carried off to the boxing-room, and deposited in large open slate compartments, before which stand a number of industrious youngsters busily engaged tumbling them out of the frames and into the boxes, where we first become acquainted with them. These boxes are packed up by the dozen or gross, ready for the numerous retail shops or the poor street hawkers, who get a fair profit even when selling them at the low rate of a halfpenny each.

We think little of such humble members of our Wonderland as match-makers and match-sellers, yet when in 1871 a tax of one halfpenny per hundred on matches and fusees was proposed, consternation spread among the poor people, and a long and disconsolate procession came to Westminster Hall to protest against the proceeding as one likely to injure their trades. At their earnest entreaty the Bill was withdrawn, though it had been calculated that such a tax would have produced over half a million. Calculate from this, if you can, the number of these trifles used in England.



A FIERY TASK.

CONCERNING IRON AND STEEL.

"We feed the furnace with lime and coke,
Wherever he makes good cheer."

FIRST about iron. If you wish to know concerning the whereabouts of the valuable metal we are about to track through our Wonderland, let me tell you that, fortunately for mankind, it is the mineral most plentifully and universally scattered about the world. It occurs in all geological formations. It lies deep hidden in the sands and clays under our feet, it lurks in the pleasant spring waters we drink, and it enters into the composition of the plants and living creatures about us. Iron, in fact, is everywhere, and may well be considered as "the metal of civilisation," for of it are fashioned alike the needle or the cannon, the pen of the teacher or the sword of the warrior. Without it man could not either dig, or plough, or reap, shoe his horses, or hold his own; the workman would have no proper implements with which to labour for his own and others' benefit, the sempstress and tailor no means of shaping or making our clothing, the surgeon no supply of needful instruments, the helmsman no compass to point out the way he should go. Gold and silver and precious stones we might manage to live very comfortably without, but iron we *must* have, for it furnishes almost every useful thing necessary for civilised life, being easily adapted to every requirement and purpose. It can be melted and cast into a thousand things, from a pan to a child's cot; it can be hammered and rolled into the large flat plates that cover our mighty ships of war, or into slighter ones to roof our houses; or it can be drawn into

endless wires, some stout enough to twine and twist into an Atlantic cable, others fine enough to snip into tiny needles (I am told of iron wires not exceeding the one hundred and fiftieth part of an inch in thickness). It will build up any number of mighty steam-engines, or it can be wrought into the handful of small nails that hold our carpet in its place; it stretches far a network of lines, on which thousands of folks can travel all over the country. In short, iron is everywhere; rich or poor, we are all equally indebted to it. Under some form or other it aids almost every man to earn his food, to cook that food, to cut it, and sometimes to digest it. Iron aids to strengthen him if he is weak, to defend himself if he is attacked, to build him a house to live in, to furnish it with many needful things, to give him the means to travel rapidly and comfortably, either by sea or by land, to carry out whatever business he is employed in.

> "To fashion the cannon that roars in the battle shout,
> The anchor, and the nail."

Surely, then, next to King Coal we may rank King Iron.

When, far back in the dim recesses of old times, no one can tell when, where, or how, men discovered a rude way of smelting iron-ore, they made their first great stride in civilisation, besides extending their dominion over the brute creation. No doubt they treated the ore in much the same way as the modern African smith still does, building up his clay furnace, through which air is allowed to pass, so as to form a draught, then piling on it layers of broken iron-ore and bits of charcoal. Some, we are told, even do without the clay furnace, and manage to smelt their ore by means of charcoal alone, the result of this being that the metal produced is easily bent about, beaten and worked into the required shapes. Dr. Livingstone mentioned this fact, saying that some of the tribes he encountered thought English iron but rotten, snapping stuff. He had himself seen a spear-like weapon of their own make curl up reed-fashion as it flew against the hard, bony head of a hippopotamus; but they soon straightened it out again, as a matter of course, with a couple of ordinary stones, and without any fire.

We feel a sort of pitying interest in the rude ironwork of uncivilised nations, forgetting that in our own land the Britons, Saxons, and even the far more civilised Romans, worked their metal in very much the same simple fashion, which indeed continued down to modern times. For remember, it is not long since the strength of animals, and next the power of water, alone aided the industry of man; iron-works, perforce on a small scale, were worked on the banks of flowing streams, and it was only when steam came to turn wheels as by magic that everything was revolutionised. Many remains of extensive Roman iron-works, or "air bloomeries," as they are called, have been discovered, especially in Sussex, Gloucestershire, and the North of England. One of these has been thus graphically described:—"Two tunnels were formed in the side of a hill, each wide at one extremity, but tapered off to a narrow bore at the other, where they met in a point. The mouths of these channels opened towards the west, from which quarter a prevalent wind blows in the valley, sometimes with great violence, so that the blast of air received by them would, when the wind was high enough, be poured with considerable force and effect upon the smelting furnaces at the extremity of the tunnel"—a

good idea. But there can be no doubt that, however cleverly managed, such chance blasts were not to be depended upon, and this must have first suggested the idea of stationary bellows, then of some kind of huge fanner which should first stir all the air about it into a state of commotion and next force it as wind into the furnace. The system still used to keep up a draught in cupola furnaces, though it is of no use as applied to huge blast-furnaces, where what is termed "blowing engines" are used.

To what part of England shall we turn that we may see the modern method of preparing iron from its first to its last stage? I read in a newspaper of the day that in

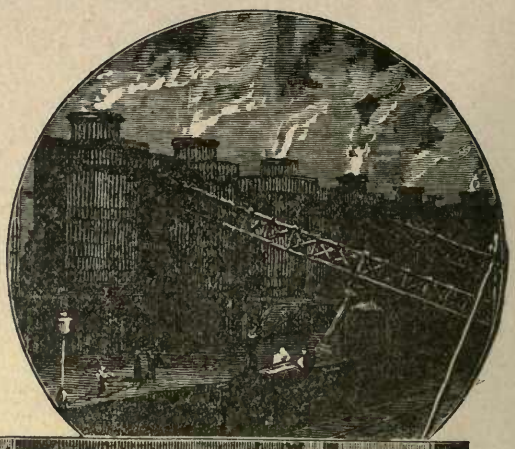
THE FIRST BLACKSMITHS.

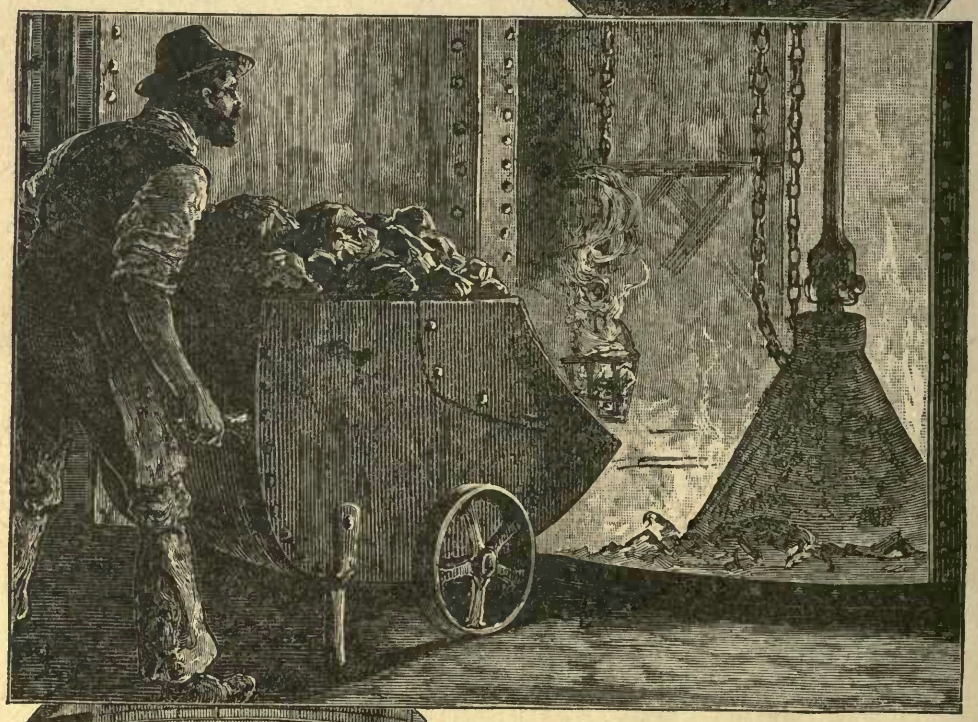
and about the north-eastern boundary of the district of Cleveland, in Yorkshire, two millions of tons of iron are annually produced. This sounds almost incredible, until the same authority informs us also that nearly seventeen million tons of ore are raised in Great Britain during the same period. If we would know more, let us hie away to this "Black Country of the North," where "the forges glow, the hammers all are ringing," and where we shall find a great iron-producing district of the most interesting kind, which has only of late risen to its present importance, for thirty years ago Cleveland, "the land of the cliffs," was a forlorn sort of place, with a scant population. In 1850 Mr. Vaughan discovered a valuable seam of limestone under Eston Moor. Since that time all is altered, and, instead of a few peasants, the place is alive with workers, a regular hive of bees, whose honey is of the most useful kind, but whose labours are of the hardest.

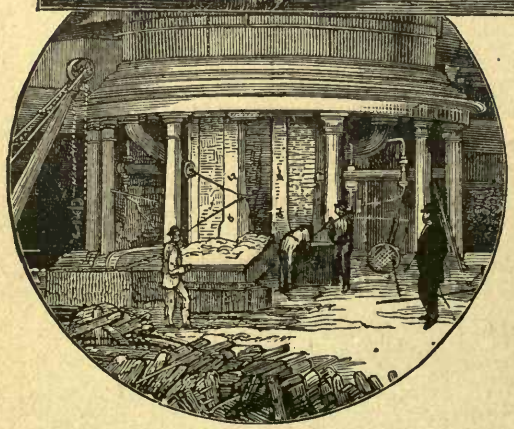
Coal and iron, iron and coal—those two mineral treasures have cast their shadow on what was evidently a pretty pastoral part of our island, though there are now but few and

far traces of this beauty, for dark blast-furnaces and puddling-furnaces have sprung up, huge and grim, in all directions; mine and anvil, and noisy forge and colliery, are to be seen every way we look; while over all hovers a great veil of thick, grey, oppressive smoke, proceeding from hundreds of tall buildings, and half hiding the fitful glare of flames that seem to fret at their endless task.

We travel on through the darkening glare until we reach the coke-making districts, where we observe a curious form of industry. Rows of odd, hive-shaped coke-ovens are glowing on either side of us; coal and coke fill trucks and waggons; we crush and crunch their powder as we walk. Everything tells of these two things—the very roads about us, as well as the colliers' cottages, are black and frowsy with the dust they scatter and the smoke they breathe. We are glad to pass on, leaving behind us those miles of dark-



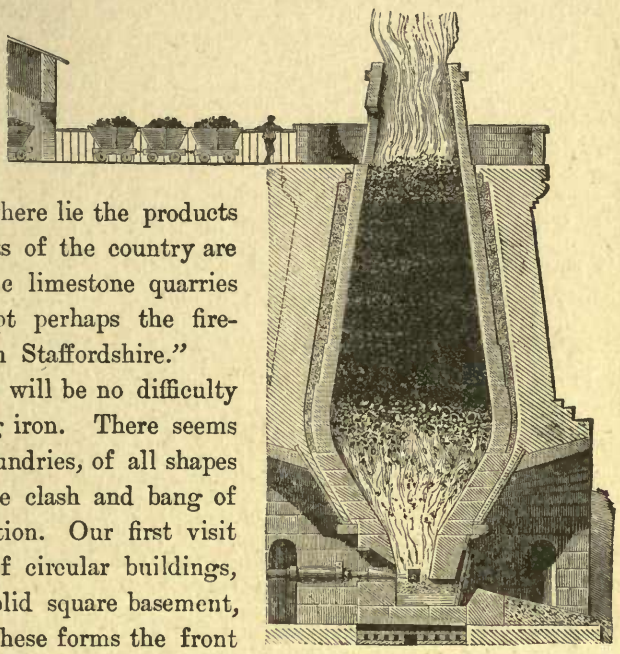




BLAST-FURNACES—FEEDING A BLAST-FURNACE—THE FURNACE MOUTH.

heaped sidings, and to find ourselves steaming onwards, looking at something fresh and green, and getting a glimpse of sunshine. But it is not for long; here we are once more plunging into another world of dense smoke, which lies heavy and thick over the great iron centre of the North. On our way to Cleveland we cannot but remember a vivid description we have read, which truly pictures the neighbourhood we are hurrying through :—

"The treeless, barren waste, the lurid fires of the everlasting furnace, the overhanging bank of smoke, the begrimed appearance of the inhabitants, the railroad running into the works, with coal and iron laden trucks moving to and fro—these mark the neighbourhood. Within are seen the numerous calcining ovens and conical blast-furnaces, the puddling-furnaces and rolling-mills, with their huge steam-hammers, the vast stacks of coal, of coke, and of firebricks, the foundry, with its chimney, and the open spaces where lie the products of mill and furnace. In adjacent parts of the country are situated the coal-mines, the iron-pits, the limestone quarries —all things needful are here, except perhaps the firebricks, which are usually obtained from Staffordshire."



A VIEW OF THE INTERIOR OF A BLAST-FURNACE.

In such a place as this surely there will be no difficulty in seeing and hearing much concerning iron. There seems to be miles of furnaces, forges, and foundries, of all shapes and sizes, and the air is noisy with the clash and bang of steam-hammers at work in every direction. Our first visit must be to one of those huge piles of circular buildings, the lower part of which consists of a solid square basement, pierced with arches. The largest of these forms the front of the furnace, and is used for the removal of the molten metal contained within its depths. Sometimes the buildings stand singly, but here several of the furnaces, all of which are built of very hard and incombustible materials, such as sand, limestone, and fireclay held together by mighty bands of iron, are set sideways in a row, so that they can all be "charged" with the different materials from a gallery which runs along the entire length, one powerful engine supplying the whole of the huge ovens with the blast of hot air which is required to keep them at the proper degree of heat.

If instead of looking up at you could look down into one of those huge, volcano-like openings, so full of roaring fire and flame, you would understand the process of cleansing iron-ore much more clearly than through any written explanation I can offer; but as such a peep is certainly impossible, for the flames within roar and spout and glare like fiery young dragons, let me try to make the matter clear from a safe distance.

Each tall and massive chimney is made of this peculiar shape, that the supply of materials for ever being flung into its gaping mouth may have room to swell and bubble and expand before it settles down at the narrowest yet strongest parts of the furnace—"boshes," I should

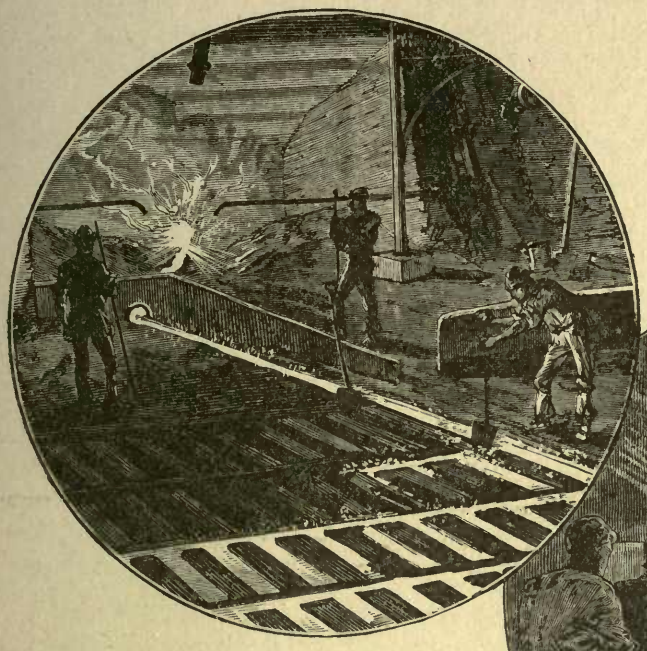
call them. Right at the bottom is the "hearth," which is a chamber or reservoir for receiving the metal, that does not really and thoroughly melt until it reaches the place I have pointed out, when, being the heaviest of all the fusible materials, it sinks into it, dropping away from all the rest, and lying in a thick molten liquid below; while just over this "hearth" are iron pipes, or "tuyères," which act like the nozzles of bellows, and carry the tremendous blasts of hot air created in the engine-room through into the fiery furnace. The heat is so great that these pipes have to be kept cool by means of chilled water or a current of cold air, to which they are constantly exposed.

Perhaps I should have mentioned something concerning the masses of crude materials poured so liberally down into that huge, hungry-looking receptacle, seemingly ever ready. They consist of roughly-calcined ore, ironstone, limestone, anthracite coal, or coke, which tumble in, heaped one upon the other in shapeless masses, to resolve themselves presently into clear molten metal, and into a cindery slag or refuse which collects and floats on its surface; for as the upper contents of this great caldron become heated and softer, the limestone attaches itself to the impurities of the iron and forms this slag, while the iron itself on its way downwards gets melted and carbonised, and fit for its first appearance as pig-iron.

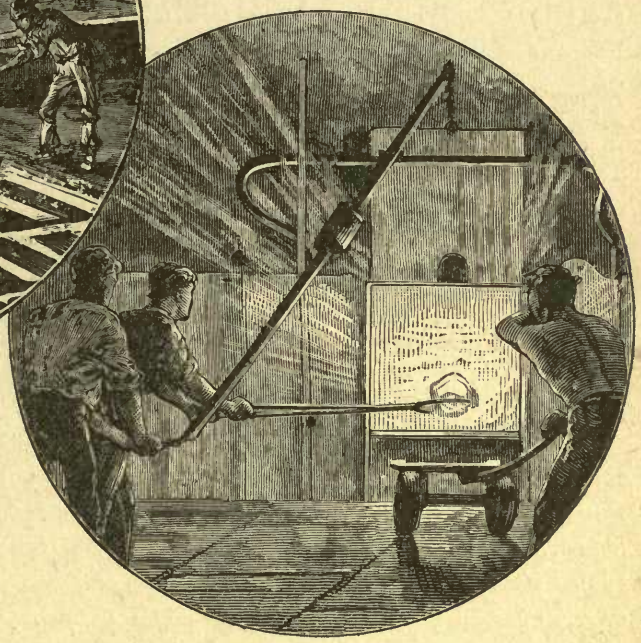
When this mighty stew, the sole object of which is to smelt and clear the rough ores, has been allowed to boil for about twelve hours, and the colour of the slag shows it is done, the glowing metal, now bubbling about the hearth, must be removed from the furnace—not into pots and pans, for, as you may imagine, nothing of that kind could contain such a fiery liquid. It has to be provided with a large, safe, and easy receptacle, into which it can flow and settle and cool at its ease, without fear of breakage. To make this possible, a very ingenious yet simple method is adopted. If you look at the space in front of the furnace you will most likely see that it is enclosed in a large roofed shed, though sometimes there is not even that, and the opening is left uncovered. In here are several men busily smoothing and levelling over a great layer of damp sand, and by means of long wooden beams, or moulds, forming it into the shape of a monster gridiron, the smaller bars of which they term the "pigs;" the larger one, that is to nourish the rest, is the "sow." For the present the "pigs" are cut off from their common parent by means of "shutters," or ridges of sand neatly arranged at their starting-point by those men with shovels, as you can see by glancing opposite.

When all is ready for the "cast," a signal is given, and one of the crowd present begins to drive a long iron bar against the "hearth" of the furnace. After some determined poking and drilling he manages to loosen and remove a thick plaster of clay and coal-dust that has hitherto kept the liquid iron in its place. A dreadful rumbling and roaring is heard going on, but that is only the hot blast or air being turned off during the casting. The man taps steadily, grasping his long iron rod with both strong, muscular hands. As the clay loosens somewhat, little dazzling spatters of red-hot metal first begin to fly about it. Soon there is a gurgling burst, and out gushes the liberated torrent, the spurt of which for a moment scatters the workers in every direction, but the next instant brings them all running up, eager to hinder this too plentiful flow by flinging shovelfuls of wet sand in its way. Soon, pouring more steadily, it rushes along the "sow" first, and that being on a slight incline fills the farther pigs to begin

with. As each pig bed brims, the barriers of sand are cleared out of the way of the next one. If the metal moves too sluggishly, it is helped along by means of long poles drawn before it and leaving slight tracks, which it follows as a stream of water will follow your finger when slightly moistened. You may imagine all this has to be done as rapidly as possible, for the metal stream in cooling soon begins to thicken and darken. When a sufficient flow has been obtained, and the pig beds are filled, the tapping-hole is hurriedly plugged up again by means of another appliance of clay and coal-dust. Wet sand is quickly shovelled over the beds of yet glowing metal, and a stream of cold water turned on to cool them.



THE SOW AND LITTLE PIGS.



THE PUDDLING FURNACE—A "BALL" OF IRON.

Very soon men can be seen striding across the bars, moving here and there amid a cloud of steam, each armed with sledges, or levers, with which they break up the as yet soft iron, separating the pigs from their parent sow, and then breaking up the sow into good-sized bars, which are now ready for market as pig or cast iron. The stamp of the founder is under each bar, having been first pressed in the sand by the wooden moulds used to form them.

The men whose business it is to attend upon these flaring and glaring blast-furnaces usually work in two relays, or sets of twelve each—one on, one off; for, as a rule, their task never ceases. These mighty ovens are alight with fire and flame Sunday and Monday, and every other day from year's end to year's end, never being allowed to die out, unless it may be for needful repairs, or on account of a failure in the public requirements; for if once allowed to cool down, they cost over £500 before they can be put into proper cooking order again. As we know, a whole row of blast-furnaces are connected one with another by a continuous platform which runs along their summits,

so that a few workers can easily feed them all; but they require several other attendants to get their varied supplies ready. Thus it is the wage-book tells of keepers, chargers, slaggers, fillers, limestone-breakers, gas-stove men, under-men, and boys, besides a number of women and girls, dirty and forlorn-looking folk, dressed so like the miners that, as happens about the coal-pit's mouth, we have to look in their faces before we can realise that they are not men. All these seem to find plenty to do, breaking, fetching, and carrying limestone, unloading coal and coke, and making themselves generally useful amid the dust and din inseparable from their work.

Should you chance to see these processes going on at night, you will be much struck by the strange, weird scene a forge presents at such a time—the red glare of fire and furnace, the gaunt and shadowy figures of the half-dressed workers darting here and there, seemingly at play with great lumps of molten metal, now apparently prodding them with a long snake-like wand, now dragging them from one part of the yard to the other, then pushing them into the clutches of clanging black iron monsters that dab and roll and fashion the glowing lumps of metal as easily as though they were merely pats of soft butter, instead of the hard unmanageable substance we know them to be. Fire, noise, sparks, steam, and panting machinery in every direction—above, may be, the quiet moon watching the active spirit of industry so busy below.

But in this very heart of our Wonderland we have no time to think of anything but the endless battle going on about us—man subduing the dark rebellious servant he has dug out of the depths of the earth. Here are the bars of brittle pig we just now saw cast, about to be puddled, and the puddler is placing them on the flat hearth or floor of a fiery reverberatory or puddling furnace. If we could look inside we should see that it has a most peculiar arched roof, which causes the flames, not the gases it contains, to bend down and meet the metal placed within, greeting it with such a hot welcome that it soon begins to soften and yield.

An intelligent overlooker gives us a half-learned explanation of what is going on within, and what are the results of this curious baking. He says that pure iron in itself is commercially impossible, and it only becomes fusible because of the various agents which are in combination with it. In the early stage of puddling, all the carbon and silicon about it oxidise; then the metal, being at last free of them, is precipitated, and forms separate grains, or granules, that are not quite pure metal, each granule being surrounded by a kind of film, which is a combination of sulphide and phosphide, adhering very closely to the iron, and to get rid of as much as possible of which is the whole end and object of "puddling."

All the while he has been talking and we listening, a tall watchful puddler has been attending to his furnace, constantly watching its contents, and every now and then stirring up the metal within by means of a long bar, or "rabble," several of which stand in a bath of cold water near at hand. He pokes and works the "charge" about through an opening in front of the furnace, taking care that every portion of it should in its turn come to the surface and meet the heat, which he constantly regulates by means of a damper.

As we watch the puddler twirling, rubbing, and teasing the glowing red-white mass hidden from view, our friend informs us that in one way this man is doing something very much like a washerwoman's work when she "dollies" the dirt out of a mass of wet linen; for

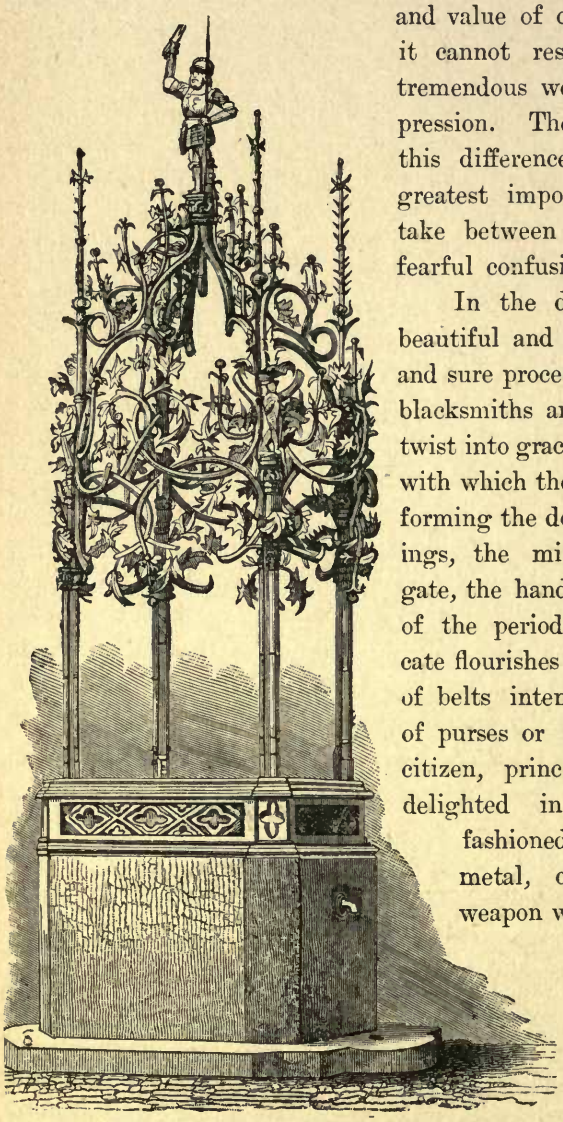
just as soapy water acts upon that, so does the constant rubbing act upon and remove the impurities, which come away in the form of cinder, and these have to be as thoroughly as possible removed before the iron can be considered quite good and malleable.

The poor puddler, who appears by this time to be nearly melting, is constantly wiping his streaming face and arms, or drinking long cool draughts of weak oatmeal and water out of a broken pitcher, all the while closely watching and stirring his work, that he tells us is "coming to nature," or one certain point at which the pure iron separates into lumps, about which little jets of gas appear to be dancing; then he turns and rolls his rod at a great rate, somehow collecting these grains into lumps, or "balls," weighing about sixty pounds each.

The removal of these fiery "balls" from their hot bed is a most exciting moment for any one who has not witnessed such a sight before. At a signal the whole heavy iron door or front of the dark furnace is suddenly lifted up by means of a counterweight, which an underhand man attends to, while the half-naked worker, tongs in hand, pounces upon the lump of pinky metal, and swinging it on to a trolley, or sometimes carrying it off himself, held fast by those long and strong pincers, places it in the jaws of a ponderous shingling hammer, which will hammer and bang it into a dense and compact mass. The more knocking about it gets now the better for the iron, which from a round, red, formless lump, we see toning down into an oblong mass, or "bloom," which is passed on to the tender mercies of the forge rolls, consisting of two great hard and heavy-grooved rollers, working against each other. One end of the iron is now placed in their jaws, and as they rapidly revolve, the mass passes between them, squeezed on its way through the groove until it comes out on the other side in the form of a rough bar. Another worker seizes this with his tongs, and passes it back to the first man, to be again rolled through in a smaller groove; until, here finished with, it has taken the form of a long flat bar, which has next to be cut into pieces, and what is called "faggoted"—that is, made up into tight bundles, very much as though they were awkward sticks of wood.

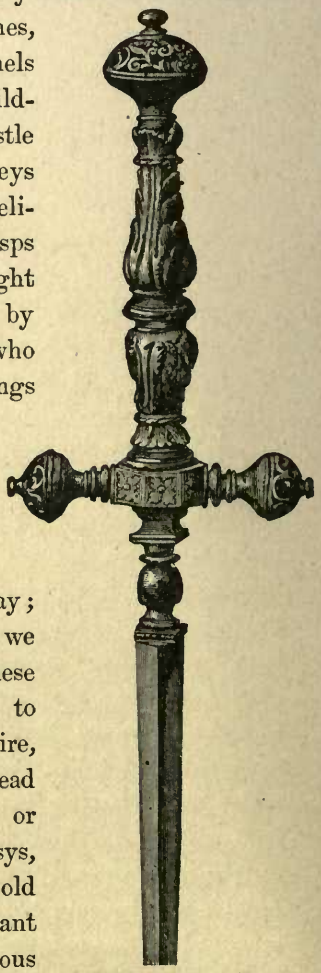
When the forge-boys, whose business this is, have finished their task, they carry the faggots piled on thin wooden framing to the "balling" furnace, where they are again heated until they arrive at welding-heat, when they must be taken out of the hot oven, placed under a mighty steam-hammer, and then again rolled in a pair of grooved rolls, only this time they are not merely turned out in straight bars, but varied in size and shape, according to the purposes for which they are intended. In ship-building, for instance, very many "angle-bars," reminding one of the letter L, are required for making the frames which hold the outside plating, they are also being made instead of being rolled into bars; the metal is sometimes passed through flattening rollers, and squeezed, and rolled, and screwed, and squeezed, and rolled flat again, until, in lieu of a bar, it has become a plate of iron, which, after having been trimmed into shape with a pair of shears which cut and snip it easily, may find its place on the sides of some mighty man-of-war. The bits of pig-iron, when changed by means of this puddling process into wrought-iron, become capable of bearing great tensile and trying strains in different directions, such as it must often encounter in certain kinds of heavy machinery, but more particularly when forming iron chains and anchors, which would be but useless things, were it not for the

tensile power possessed by the metal of which they are composed. So important is this from a sailor's point of view, that all such things supplied to our Navy have to be officially tested before they are passed and pronounced fit for use. Strangely enough, the property and value of cast-iron lie in exactly the opposite direction; it cannot resist stretching or twisting, but it can bear tremendous weights, and any amount of pressure or compression. The thorough understanding and allowance for this difference between wrought iron and cast is of the greatest importance in all engineering work, as any mistake between the virtues of the two metals would cause fearful confusion and damage.



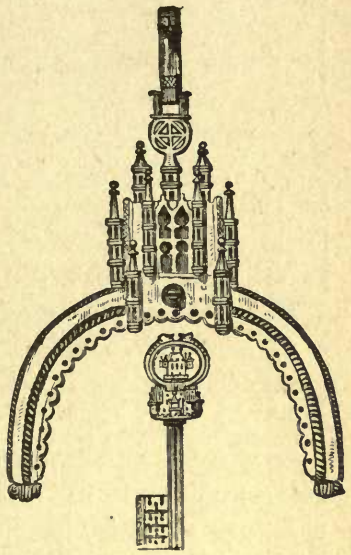
WROUGHT-IRON FOUNTAIN.

In the days when little was done in cast-iron, very beautiful and artistic designs were carried out by the slow and sure process of hammering the metal, which Continental blacksmiths and locksmiths had early learnt to beat and to twist into graceful curves and flourishes, with which they ornamented the panels forming the doors of their public buildings, the mighty locks of the castle gate, the handles of the fanciful keys of the period, or even the more delicate flourishes about the heads or clasps of belts intended to bear the weight of purses or pouches, worn alike by citizen, prince, and noble lady, who delighted in the graceful things fashioned of this unlikely metal, of which many a weapon was daintily chiselled. But, unfortunately, iron rusts, and slowly but surely passes away; so that, therefore, we have but few of these early works left to wonder at and admire, excepting, indeed, the light scrolls which Biscornette, the smith, spread as hinges over the doorways of Notre Dame and other churches, or the graceful fountain which the better-known Quentyn Matsys, "the artist-blacksmith of Antwerp," left to grace the quaint old town he loved. To us it seems strange to remember how the ignorant populace of those times held these skilled workers in superstitious awe. Not being able to understand how out of a mere straight bar



SWORD-HANDLE OF WROUGHT-IRON.

of iron such beautiful fancies could be carried out, they declared it must be by the aid of magic; and when this same clever smith, Biscornette, suddenly and mysteriously disappeared from his home and beloved forge, it was secretly whispered that the Enemy of Mankind had claimed the artist's soul as the price of the power he had endowed him with—one peculiarity of the good old times being that when any man had genius and industry beyond his fellows, as well as the determination which enabled him to achieve things far out of the common track, he was invariably accredited with having obtained the assistance of the Evil One, and was in consequence avoided and held in holy horror by many of those ignorant folk who could not understand the use he was making of the talents with which the Master had endowed him. Surely things must have changed for the better, as, under the same circumstances, he is now reverently believed to have received his gifts from God; and if he employs them for the good and advancement of his fellows, he is sure of being respected and encouraged by all about him.



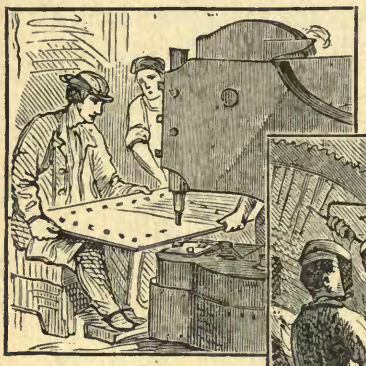
CLASP AND KEY OF A PURSE OF THE FIFTEENTH CENTURY, IN WROUGHT-IRON.

Curiously enough, many Abyssinians—who are well armed, and owe so much to their workers—look, it is said, with mingled respect and horror upon their skilful blacksmiths, believing that they must be aided by magic, and have the power of transforming themselves into hyenas, and wandering about the woods after nightfall to devour all whom they chance to meet. Workers in iron are therefore avoided as much as possible, more especially as they have also the credit of causing harmless folk to become possessed by the "Buda," or evil spirit, whose ugly spell is worked by twisting a blade of grass into a circular form. Should the grass break, it is believed the victim dies at once; should it remain circular, he is possessed, and afflicted with dreadful fits—no doubt of epilepsy—which can only be relieved by music and dancing, or the use of certain mystical charms, at the mere touch of which the "Buda" will succumb. The victim to the ironworker's malice tries every night to escape into the woods, where the evil-minded blacksmith, in the form of a hyena, is said to be waiting to devour him. Sometimes the "Buda" will, through the lips of the person possessed, reveal the sorcerer's name, in which case the friends of the sufferer will lay in wait for and try to capture the hyena, which they believe they can prevent from returning to his natural condition of a blacksmith until he has restored their unfortunate relative to his original form and nature.

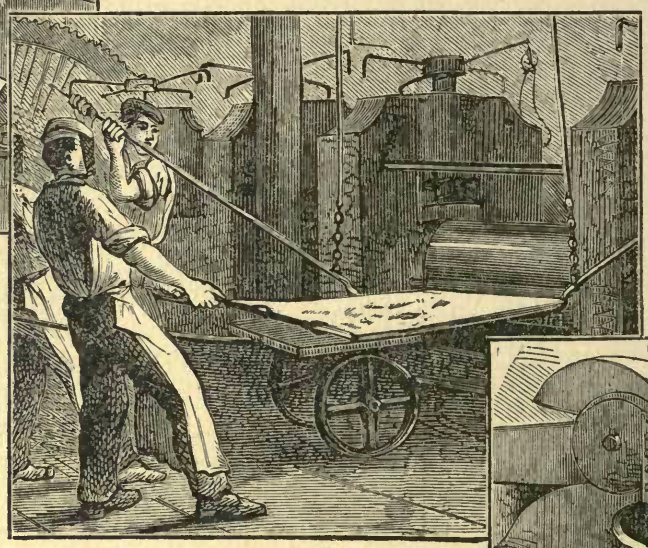
But to return to the busy forge, noisy with the din of ironworkers and the clang of the big steam-hammer. Let us cross the yard, and watch the various processes going on in that large, half-open shed, where we are told the iron is being rolled into sheets. The first thing we notice on entering is, that we are treading on a floor neither of wood nor stone, as in most "shops," but of hard and shining metal, bright with much rubbing and the tread of many feet. In every direction are sets of rollers, great revolving wheels, and a pair of monster shears, the upper half of whose steel jaws is for ever opening and

shutting in a hungry fashion, that somehow makes us shudder with a notion that it would snap a head off quite easily, and, like some monster of early fable, rather enjoy the doing it.

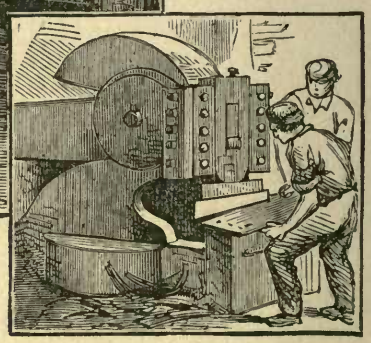
Here, too, we find another great fiery furnace, which one man is keeping open while a second sturdy worker is dragging a lump of glowing metal out of its pinky recesses. As he swings it forth, clenched fast at the end of those long tongs, we cannot help noticing that it is very like one of those sturdy bars we last saw being patted about and dealt with by the "shingling" hammer. He turns and twists and swings the heavy red mass, until, by what seems to be some sleight of hand, but which is, of course, only professional dexterity, he has pushed one end of it between two ridges in the rollers, which consist of a graduated series of such ridges, each one so shaped as to narrow the space between which the metal must presently pass. Once in, the bar gets such a squeeze that it rolls out much flatter and thinner than it was when it entered. It has quite a curve upwards now, of which curve the worker takes advantage, for by this he coaxes it to re-enter the rolls. In it goes, and out it comes again, each time getting more and more of a squeeze, until after perhaps half-a-dozen journeys in and out, the solid bar has changed into a long, helpless-looking strip of whity-red metal, which is now hurriedly seized upon, and carried off to those ever-opening shears, that with two snaps will have clipped off the rough ends, and with another will have cut the strip in two as easily as though it had been a sheet of cardboard.



PIERCING IRON.



ROLLING SHEET-IRON.

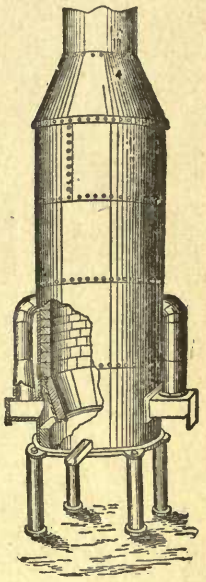


SHAPING IRON.

As these two halves of our bar come apart, they are carried off to another kind of machine, with long, smooth rollers, that also eagerly seize upon one end of the metal presented to them, and squeeze and roll as the bars constantly travel backwards and forwards, getting thinner and longer yet, for the upper space has been narrowed and narrowed by means of tight screws; and still the metal has been forced to squeeze through, until at last the bars are transformed into flat sheets or plates, some thirty feet long. If they are required to be of a medium thickness, one is now laid above the other, and they are rolled together; but if a very thick sheet is required, the one would be rolled alone.

In the case of these very thin and light sheets, so much used for roofings or other purposes, and, when prepared with zinc, known as "galvanised corrugated sheet-iron," from four to six of these pieces are rolled at the same time.

There is a smaller tower beyond these large ones, which the workers often refer to as the "cupola furnace." It looks very much the same as a blast-furnace; but we will find, on inquiry, that it is only used to melt iron that has already been smelted. It is by means of these cupola furnaces, built of firebricks and lined with iron, which are to be found on almost all engineering works, that "castings" in iron are taken—a very curious process, which we will stay to witness, the more especially as we meet with cast-iron goods in many forms, from workshop gas-branches to our iron bedstead.



A CUPOLA FURNACE.

We notice that the chimney of the furnace is very much smaller than that of its big brothers, therefore it requires much less "charging," and, instead of mighty engines, it is supplied with air by a flying "fanner," which supplies it with a cold instead of a hot blast. Indeed, the "cold blast" is usually much preferred for all cast-iron objects, especially those which are particularly required to resist compression.

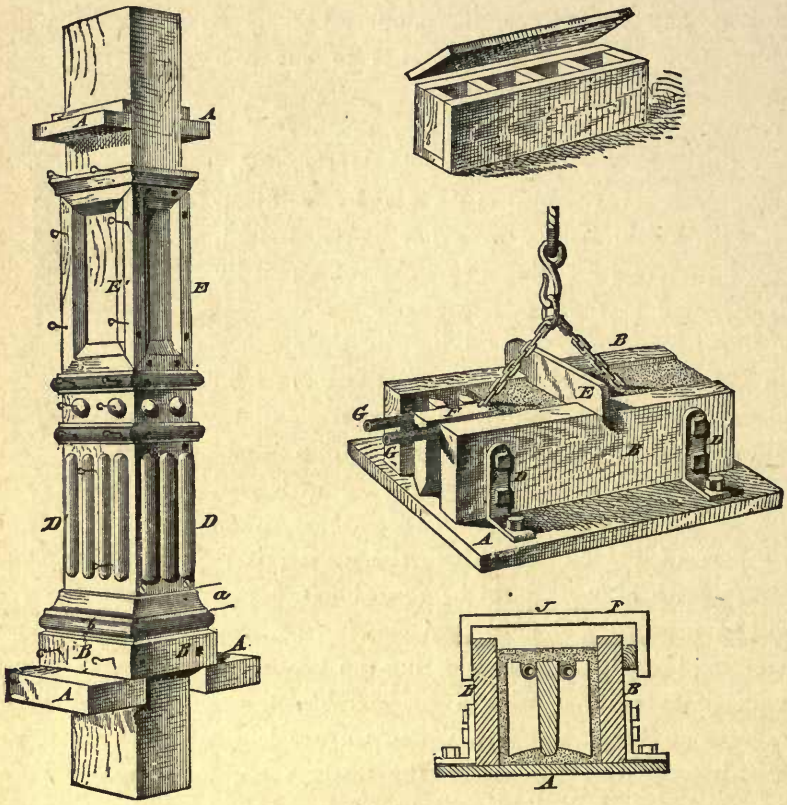
We know all about the blast-furnace pigs lying in their sandy bed, and the tapping of a cupola furnace is very much the same kind of thing. There is the plaster of clay and coal-dust to be removed by the worker's rod. Then the molten metal pours out, not into a sandy bed, but into a large ladle or pot made of cast-iron and lined with sand and clay. Some of these are small enough to be easily carried off, when filled, by two men, to that part of the foundry where the casting is to take place. But when a large piece of work is to be turned out, a proportionately large "pot" will be required, and more than one furnace may have to boil up a supply of seething broth before such a casting can take place.

The floor of every foundry is covered with a considerable thickness of the very finest sand, which, however, looks so black and grimy that we can hardly guess what it is. All about us we see the cast-iron "boxes" in which the castings are to be made; they are of every variety of shape and size, but all consisting of two halves, an upper and a lower one, crossed with thin plates to hinder the sand from falling out when the "box" is tumbled all ways.

Here is a man about to cast a number of small cylinders, of which he has the wooden model at hand. He first proceeds to fill the lower half of a "box" with the sand, which lies massed in such plenty under his feet; then he lays the model in so that its lower half is embedded tightly and evenly; next he replaces the top half like a lid on the "box," and fastens it down securely by means of projecting bolts or pins. More soft sand is now poured in at the open top, pressed and packed tightly until it has taken the impression of that upper uncovered half; then the box is opened, the model lifted out of its bed, leaving exact impressions or moulds of the upper and lower halves on those two half layers or sand-patterns, which the pressure has fixed so firmly into shape that the moulder is able to touch them up here and there where the sand seems not to have

fitted quite neatly before dusting it over with lampblack or charcoal, before taking his cast, which he does by again fastening the two portions of the box together, this time with no solid model in them, and pouring the molten metal in at a hole or channel which is left for the purpose. When cold he opens the box and turns out a completed solid object of the exact shape we just now saw left hollowed out in the sand.

We have only seen the casting of small solid objects; the casting of larger things is evidently a very much more difficult and elaborate process, the patterns being made in pieces so that they can be taken apart in the moulds. Here, for instance, we have a pattern and a mould for an ornamental pillar for a building, and some of the panels are merely held on by pins, so that after it is in the mould the pins can be taken out, and the box body of the pattern can be lifted out without disturbing the moulded panels, which are taken out afterwards. The pipes, whose ends you see sticking out at the end of the mould at G, are for letting out the gases generated by the molten iron, which would, if it did not have a free vent, cause an explosion in the mould. Very large castings are often made in moulds that are built up of brickwork, merely covered an inch or two thick with loam, which is swept into shape by the edges of boards that are given a profile to correspond to the shape the casting is to be. These boards are called "sweeps," because they are swept around the mould, and sometimes swing from a central column.



MOULDING A BUILDING COLUMN.

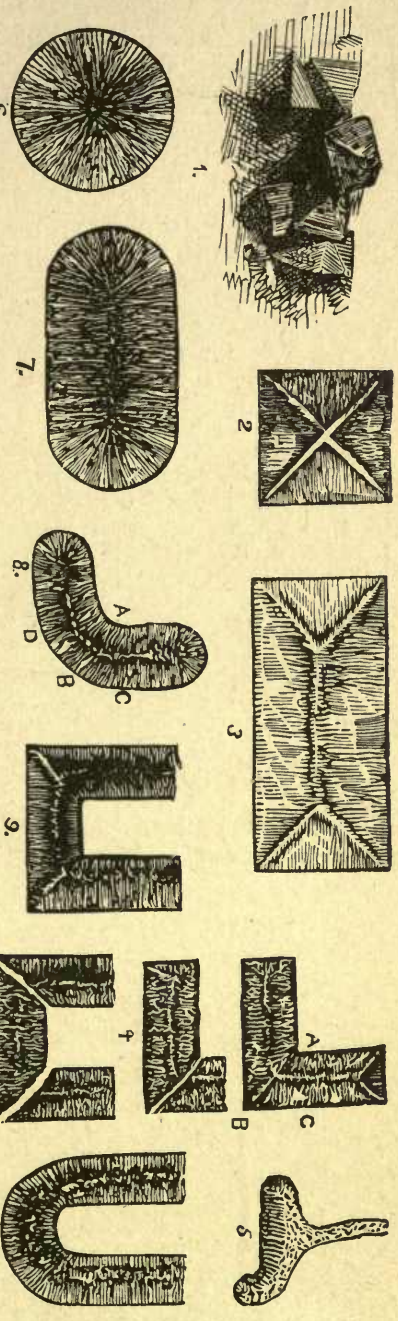
If we break a casting after it is cold we find that it looks more or less granulated or crystallized, like loaf sugar; and we may find upon proper inspection that these crystals are of an eight-sided form, just as we might imagine to be formed by two square pyramids placed with their bases together. Curiously enough too, these crystals so form themselves as to be lengthways to the direction in which the heat passes out of the molten metal as it cools, so that in every differently shaped piece of work the crystals

are arranged differently. In a perfect crystal of iron all the lines joining opposite angles are of equal length, and at right angles to each other; but as the heat passes out of the casting through the top of the mould, the crystals arrange themselves perpendicular to the casting as it lays in the mould, and this often causes the casting to be weakened, because the crystals do not join properly in the corners and angles. At 1 we here see a group of iron crystals, among which one has succeeded in assuming its natural form. At 2 is an end view of a broken casting of a square bar. At 3 is a similar view of a rectangular bar, the diagonal lines being in each case lines of weakness.

In all the examples the pieces of circular form are shown to have the crystals joined more closely at the centre, and it is plain that they are for equal weights the strongest, and this is why you see the castings for modern machines have as few sharp corners as possible.

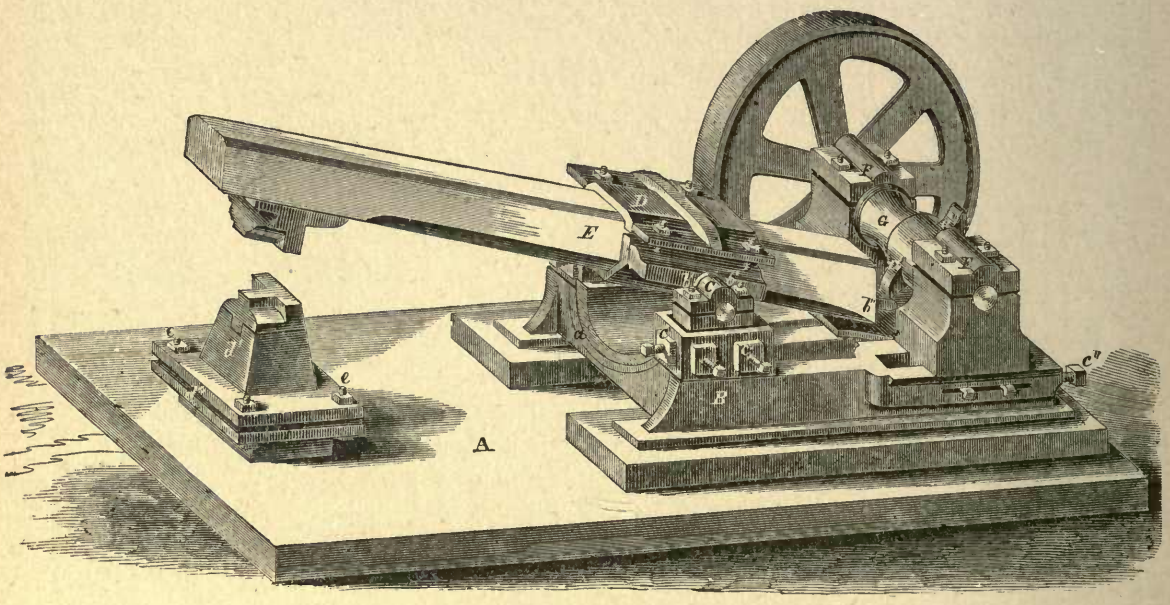
As we retrace our steps through the busy foundry we must once more pass that mighty steam-hammer, the sight of which is not easily forgotten, as it steadily and unfailingly does the work of many men in such a quiet yet giant-like fashion that it is difficult to realize how much it is doing, though easy enough to believe that such a powerful machine as this must, since its introduction, have effected a very great revolution among ironworkers, who, before this monster assistant, had but the helve hammer to aid them.

This helve hammer was simply a pole fastened securely at one end, and having at the other the hammer, which was set in a swinging motion by foot pressure applied on the downward stroke, the elasticity of the pole acting to lift the hammer up again after the blow was struck. For many years this primitive appliance was all the blacksmith had for striking the heaviest blows, but it would surprise you to see what large pieces of iron could be forged with it.



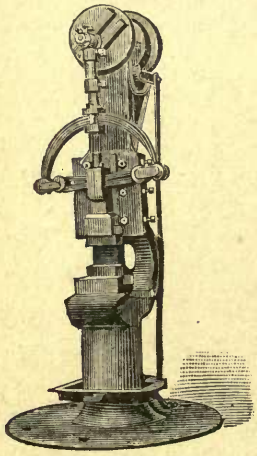
THE GRAIN OF CAST-IRON.

Here we have a modern form of the helve or *trip hammer*. The two lugs or projections (*a*) on the shaft (G) striking, as the shaft revolves, against a lug on the end of the wooden beam (E). The wheel is for the belt or strap that drives the hammer. The shapes of the dies are made to suit the work, or plain flat-faced dies may be used for simple forgings. Trip-hammers are noisy fellows, but they are very efficient in skilful



A TRIP-HAMMER.

hands, as will be seen by a very curious feat that may be performed with them, which is to take a bar of cold wrought-iron and hammer it so quickly that it will actually get red-hot from the heat caused by the hammer blows.



POWER-HAMMER.

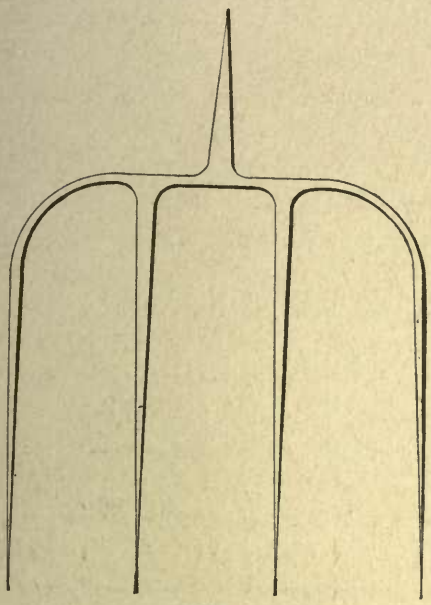
There are many different forms of trip-hammers, some having springs and some rubber cushions to give the hammer a dead blow, as it is called, and prevent noise. Here, for instance, is a power-hammer, as it is called, in which the hammer is slung from a spring by leather bands, and a crank pulls the spring up and down, and causes the hammer to reverse its motion easily, while it is quite free when it strikes its blow, for which reason it is called a dead stroke power-hammer, the word "power" meaning that it is driven by a belt. In former times these hammers were used to roughly block out the work only, but nowadays they are used to finish it complete, even though it be of quite intricate form, giving to it a black polished finish that is finer than can possibly be given with the blacksmith's hand tools.

Much of the work done under the trip-hammer requires a great deal of ingenuity as well as of skill to make it, as we may see by taking as an example a common four-tined

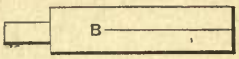
stable fork, to make which the blacksmith is given a piece of rectangular steel 5¾ inches long, 1¾ inches wide, and half an inch thick.

This is a queer-shaped piece of steel to forge a stable fork out of, but it is easily and quickly done. First, the blacksmith forges down and rounds up one end as at A, then he cuts a split through at B, and opens out the split so as to form two legs; next he forges a recess at C, cuts two splits as at D D, and opens out the split pieces, thus forming four legs, E E and F F. He draws out the two tines E E, and afterwards the two tines F F, and bends them around into shape, producing the finished article as you see it.

MAKING A STABLE FORK.

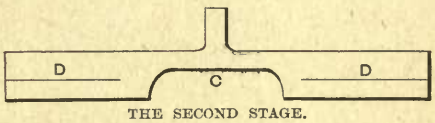


THE FINISHED FORK.

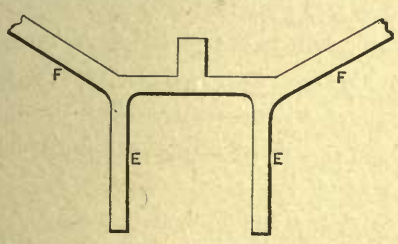


THE FIRST STAGE.

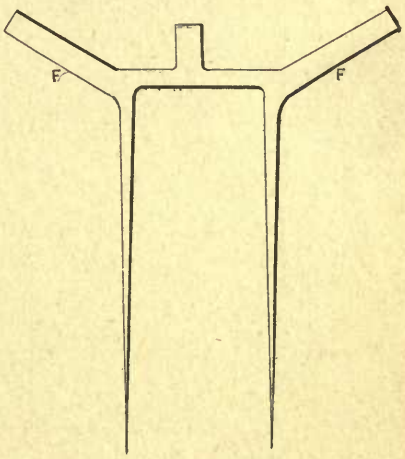
If you go over this interesting process again you will be able to observe one fact that is very important in so slender a tool as a fork, which is that the grain of the steel runs lengthways throughout every part of the fork. But you may not have heard that steel has a grain, and so we may as well explain how it gets it. Well, when an ingot of steel is cast, it is composed of crystals, and as the ingot is rolled or forged into long bars these crystals are lengthened out in one direction only, spreading along the bar length, and it is found that the bar is stronger across the grain than it is in a direction along or with it. Now you will observe that in our stable fork the process of shaping and forging has been such that if it broke anywhere it would have to be done across the grain.



THE SECOND STAGE.



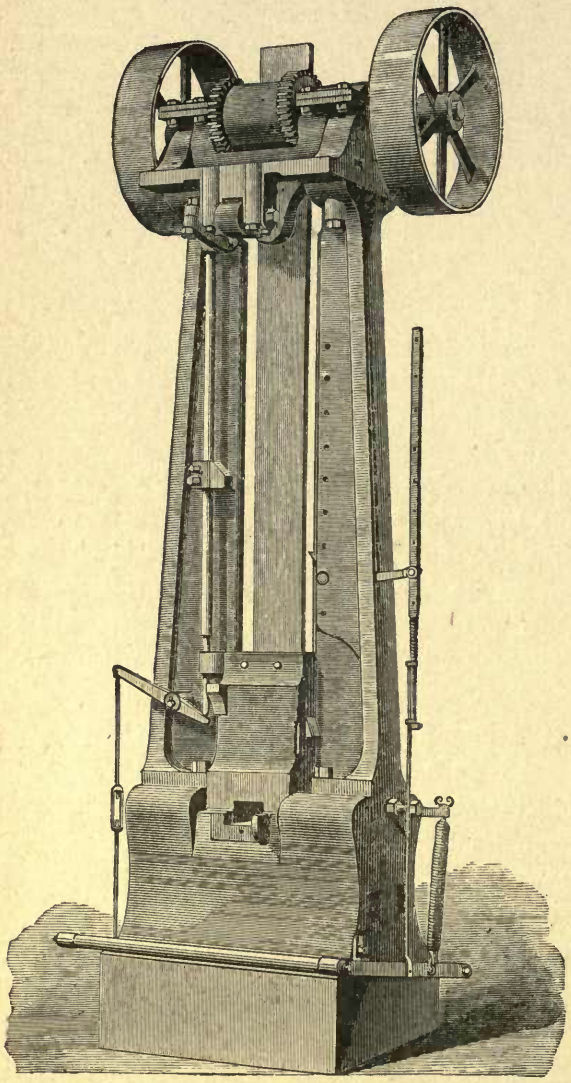
THE THIRD STAGE.



THE FOURTH STAGE.

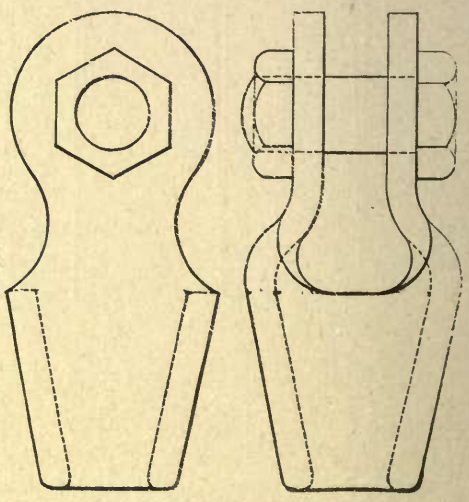
A great deal of small work is forged under the drop-hammer, which is composed of an iron frame, carrying at the top a pair of gripping rolls, driven by a pulley. A long plank reaches up from the top hammer and passes between the gripping rolls, which, after raising the hammer, release it and let it fall to strike the blow, whose force depends upon how high the hammer was lifted before being released. The work may be forged with a plain-faced hammer and anvil block, or between dies, which form it to the required shape. But obviously for very heavy work the trip and drop hammers are too

puny and light, and the massive steam-hammer comes in to play, the heavy blows shaking the ground beneath your feet, although you may stand forty feet away. But you must not suppose that steam-hammers, are used for very large work alone, for they are sharp competitors with the trip-hammer, even on small work, and as much or more skill is required to use them.



A DROP HAMMER.

Here, for example, is what has been considered a very skilful example of steel forging under the small steam-hammer. It is a rope "socket"—that is, a socket for holding the ends of the wire rope on the New York and Brooklyn Bridge; and this is how it was made. The blacksmith took

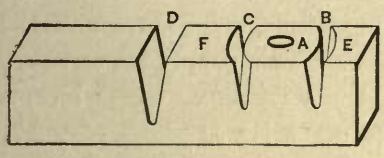


THE FINISHED ROPE SOCKET.

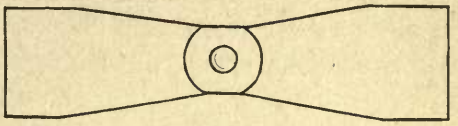
a bar of steel and punched into it a hole at A. Then he took two curved *fullers* and cut two gashes, one at B and another at C. These gashes he widened out with a second fuller, and cut the piece off from the bar at D. Both ends of the pieces then looked as you see it at E, and he forged out first one end into the shape at E, and then the other, thus forming two wings. Then he put the forging into a die-block (G), drove in a plug or punch (H) to enlarge the hole and make it taper, and then bent up the wings. All he had to do then was to put in a mandril (I) and two wedge-pieces (J and K), to keep the hole from closing up, and dress the whole forging to finished shape. This, you see, is quite a straightforward process, and yet what a number of forms this simple piece of work passed through to transpose it into the required shape! Some of these sockets weighed

as much as 80 pounds, and it was thought so difficult a forging to make that several good blacksmiths declined to undertake their manufacture.

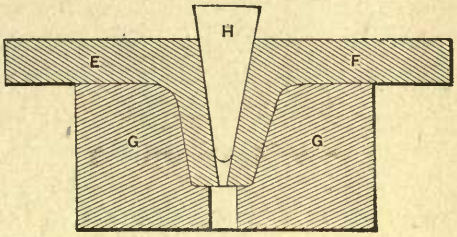
MAKING A ROPE SOCKET.



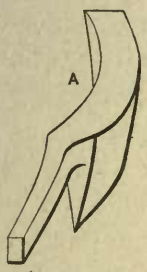
THE FIRST STAGE.



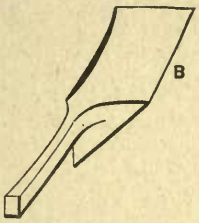
THE THIRD STAGE.



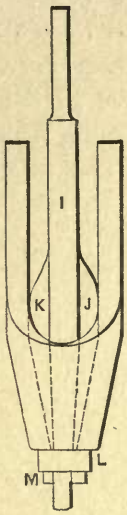
THE FOURTH STAGE.



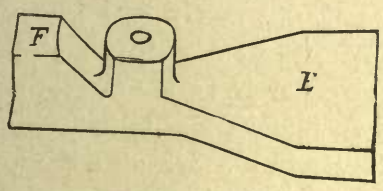
THE FIRST SWAGE



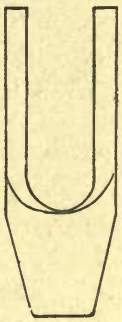
THE SECOND SWAGE.



THE FINISHING STAGE.



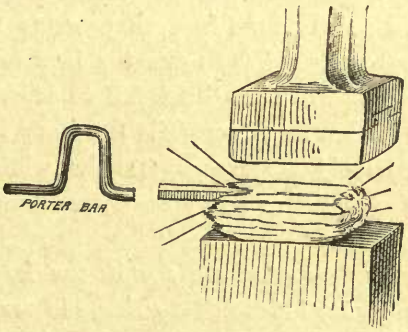
THE SECOND STAGE.



THE FIFTH STAGE.

Standing at the great open doors of the blacksmith's shop, where the ponderous steam-hammers are at work, we shall see that the scrap-iron, as it is termed, is brought back to be forged into blooms, to be used in making new forgings. Here, for instance,

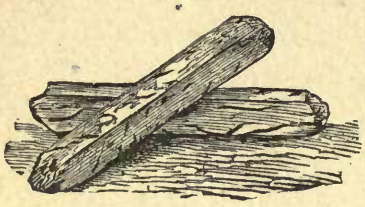
A PILE OF SCRAP-IRON.



FORGING A BLOOM.

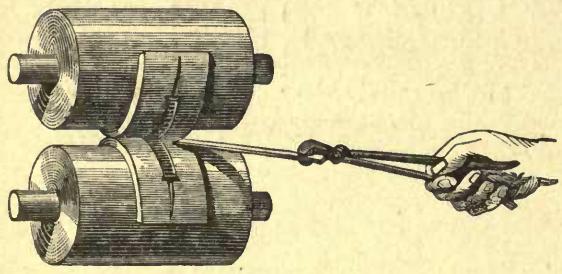
you see a pile of scrap ready for the furnace. It is piled upon a piece of board half an inch thick, about 10 inches wide, and 16 inches long, and is composed of selected scrap,

such as the clippings of boiler plates, old rivets, bolts, and horseshoes. It goes to the furnace, and is heated to a welding heat. In order to enable it to be handled, it is welded to what is called a porter bar, which has a crank, by which the bloom can be turned over and over during the process of forging. When completed the porter bar is cut off, leaving the bloom, which has rounded and ragged-looking ends, and a surface full of lines that look like cracks, but which simply show where the pieces of the pile joined one another. These blooms are again welded together to make larger pieces of work, which is of all the better quality for having been made of selected scrap, for wrought-iron is one of the very few things we have that improves by being worked up over and over again. The long bars of iron you see in the blacksmith's shop piled in racks ready to cut up for use, however, are made uniform in size and true to shape by passing them through the revolving rolls of a rolling-mill; and I may tell you that a good deal of forging is done by rolls having projecting pieces on them, in which are cut indentations having the shape the forging is to be.



BLOOMS.

Only comparatively thin and light pieces, such as knife-blades or the leaves of carriage springs, can be forged in this way. In whatever way a piece of work is done, you will always find a good sound reason for it; and in this case I may tell you that the impressions are sunk in the projecting pieces to avoid having to pass the work entirely through the rolls, because when these pieces are out of the way, which they will be as the rolls revolve, the smith can put the bar through them, and up against a stop, so that when the projecting pieces and dies meet the work they push it back to the workman while squeezing it into shape.



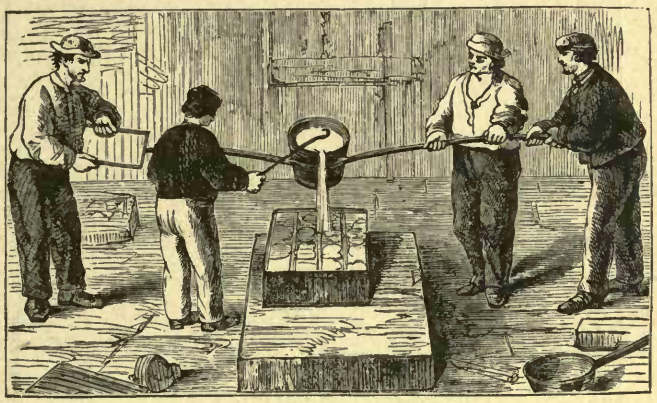
FORGING IN ROLLS.

The blacksmith must be a man of decision and quick perception, as well as being strong and active, for his work presents new phases at every moment, and he must act promptly, because if he heats the iron too often without well working it its strength is ruined, and it will sometimes fall to pieces as he lays it on his anvil. He must therefore do nearly all his thinking while the work is in the fire, for as soon as it is on the anvil he must, as the old adage says, "strike while the iron is hot," and so, as you see, whether the blows are light or heavy ones, the brawny arms must repeat them as rapidly as they can be delivered.

The forgings that we see in the large blacksmith's shop are usually rough because they are afterward finished to shape in various kinds of metal-cutting machines, but many light forgings are made clean and shapely, having a black-looking finish that is very pleasing to the eye. In order to produce this finish the scale that forms on the outside of the iron when it is made hot enough to forge easily must be cleaned off before the forging is done, and for the final finishing the iron is not heated above a blood-red heat,

and the forging is continued until the iron is down to a low black heat. There are, you must know, a great many kinds of wrought-iron, and the blacksmith must be careful in its selection for some kinds of work. Among the most ductile and softest of irons are Swedish and Norway, which may be tied in a knot while cold without breaking. Low Moor iron is an English iron celebrated for its toughness and strength, and Burden's best is a superior quality of American iron.

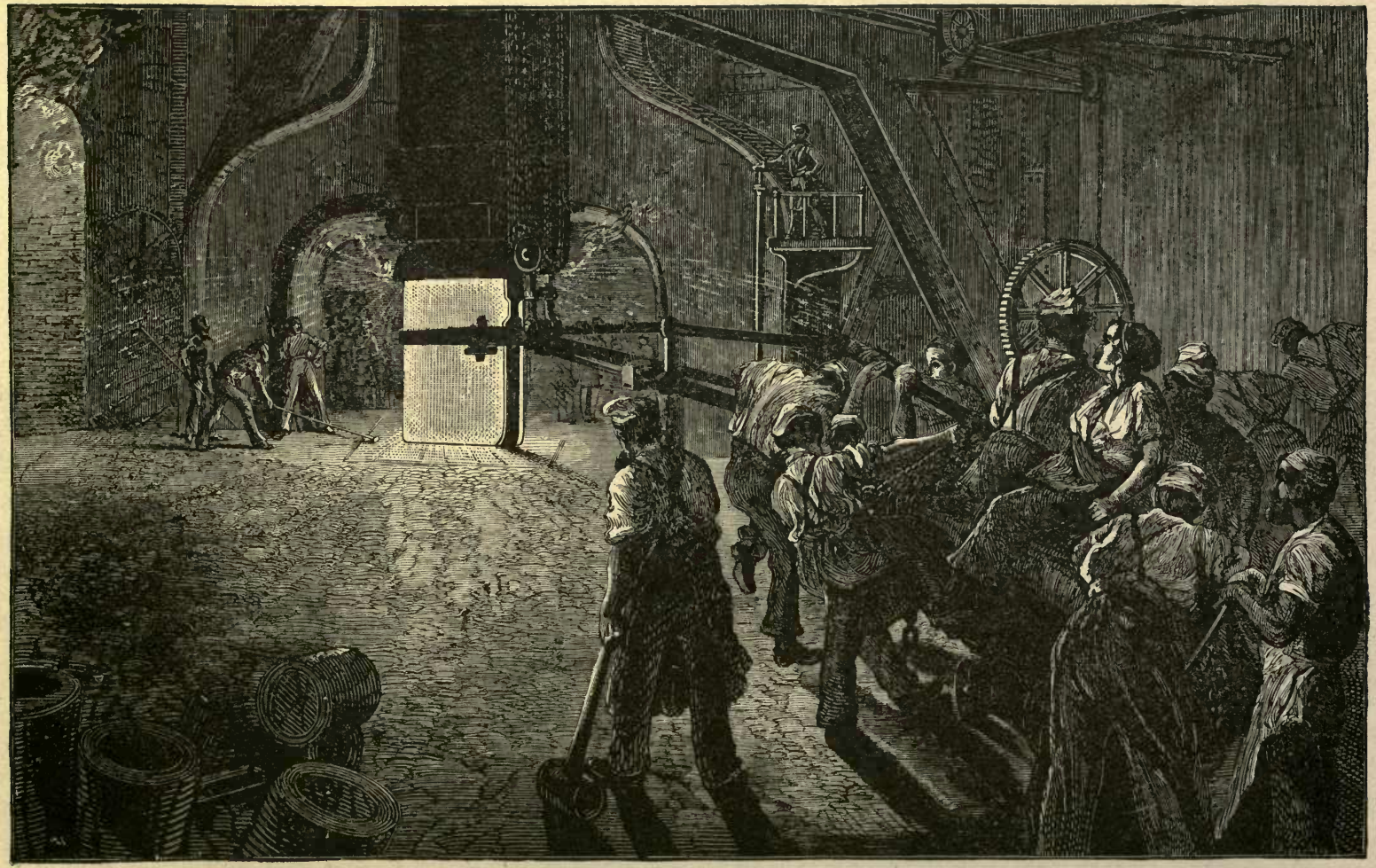
As we linger once more to watch these men standing in the red-hot glare cast about it by the mass of white-red iron they are placing on the anvil-block, we are reminded of Nasmyth, the improver and patentee of the first huge hammer of this kind, concerning the uses of which a great authority says:—"It has given an impetus to the manufacture of iron, and afforded facilities for the welding of large blocks of malleable iron that could not be accomplished by the tilt and Helve hammers formerly in use. We have only to instance the forging of the stern-posts and cut-waters of iron ships, the paddle-wheels and screw-shafts of our ocean steamers (some of them weighing upwards of twenty tons) to appreciate the value as well as the intensity of action of the steam-hammer."



CASTING SMALL OBJECTS.

When Nasmyth was but a little lad, the youngest of a family of ten, nothing delighted him more than to spend his half-holidays and spare moments in a neighbouring forge that belonged to the father of one of his schoolfellows. The boy did not merely go staring and wandering aimlessly here and there, but was always intently watching and trying to understand the different processes through which the metal passed, learning all the details of the moulding, casting, forging, and smithing work going on about him, so that when, after long years of hard work and self-denial, he became exceedingly prosperous, he was glad to remember how much he had learnt in those days, and often declared that the time spent in the different small shops connected with that foundry was the true and only apprenticeship of his life. No bad apprenticeship either for such a clever, industrious lad, "with eyes," and determined to understand as well as to see.

Not only is Nasmyth's mighty steam-hammer worth watching and wondering at, but some of his words are worth remembering; for instance, when, addressing young workers, he said:—"If I were to try to compress into one sentence the whole of the experience I have gained during an active and successful life, and offer it to young men as a rule and certain receipt for success in any station, it would be comprised in these words—'Duty *first*, pleasure *second*.' From what I have seen of young men and their after-progress, I am satisfied that what is generally termed 'bad fortune,' 'ill-luck,' and 'misfortune,' is in nine cases out of ten simply the result of inverting the above maxim. Such experience as I have had convinces me that absence of success arises in the great majority of cases from want of



STEAM-HAMMER AT WOOLWICH ARSENAL, FORGING PART OF 80-TON GUN.

self-denial and want of common-sense, the worst of all maxims being, 'Pleasure first, work and duty second.'" Good advice, and well worth consideration surely.

Perhaps the place where we might least expect to find iron literally growing is in the beds of lakes and rivers; yet such lake ores exist in great profusion in Sweden, more especially in Smaland, where the strange "water-mining" keeps many people busily employed at certain seasons of the year. Though all this iron can be smelted in the ordinary way, there are several varieties and qualities to be found. There is the hard and heavy "pearl" ore, which has to be raked up from muddiest depths; the "money" ore, so called from its fancied resemblance to coin, but it is not of a very good quality; the greenish "gunpowder," lying in close, heavy grains among the sands from which it seems loth to separate; and the "burr," thought to resemble the head of the wild burdock flower, and which lies so light and spongy on the grassy beds far out of sight in the depths of those picturesque lakes for which Sweden is unrivalled.

All these ores, mixed with many impurities which have to be carefully extracted, are to be found about the reedy banks or on the slopes of shallows. Up the deeper waters they usually lie spread in layers of from twelve to two hundred yards long, but never so as to meet a strong current; and, strangely enough, the ores vary according to their position in a stream. Thus at its commencement "gunpowder" may be met with; then "pearl," "money," and "cake" will be turned up by the industrious explorer, who, could he succeed in carrying all these away with him, would not exhaust the wonderful mine, which in time will once more be rich with just such another store of this treasure among minerals, that learned folks therefore surmise must be of an infusorial origin. In the short and pleasant summer time a great deal of ore is dragged up from the depths by dredgers in boats floating on the surface of the lakes; but when autumn touches the waters with its icy hand, workers well practised in the search come out to prospect for iron, which they do by making small holes in the ice, and then feeling about beneath it with the end of a long and slender pole until they feel that they are in a promising place.

Two men are usually associated in this search, and when they have thus found a likely spot they mark out a certain boundary about it by sticking twigs in the ice, which gives them a legal right to work in this place during the bitter winter which is near. As soon as the ice is hard and safe enough for their purpose, our partners take possession of their "claim," as a digger would say, and set to work in earnest by first making an opening of about a yard square, and through this letting down a kind of iron sieve or perforated plate which is fixed fast to a long rod. Then having collected all the ore they can drag and scrape together by the aid of a long rake, they push it on to the plate, which is then worked up, with its wet contents, mingled ore, mud, sand, and clay. To cleanse this mass somewhat, it is put on another perforated tray, which is lowered a very little way into the water, where it is shaken and worked about until a great deal of the rubbish which came up is washed away, and the ore left comparatively clean and ready. As I have described it you may think all this a very slow performance. Yet it is said that when they are working a good hole, two hardy strong men can sometimes collect as much as a ton and a half of ore in a day, and that in one year 22,000 tons of bog and lake ore were thus collected in Sweden alone.

But our really "precious metal," though it is not so termed, is usually found hidden away underground, and not under water, in combination with various earthy substances. When found it presents but a dark, unpromising outside. In this state it is known as "ironstone," and its quality varies according to the country and district in which it lies—some being much richer than others in pure iron. Sometimes this "stone" contains clay, but no lime; sometimes lime, but no clay; sometimes even a small modicum of coal; but at any rate it contains a proportion of water. Flint, sulphur, and carbonic acid are almost sure to be present in the ironstone, which is usually discovered in beds of varying

A FAMILY OF SWEDISH PEASANTS PROSPECTING FOR LAKE ORE.

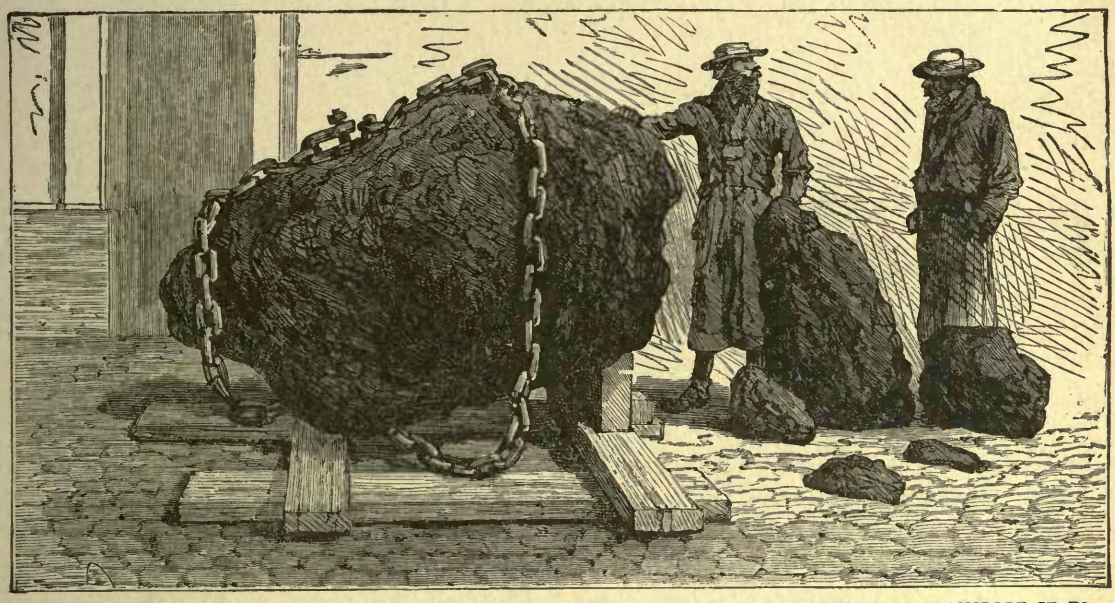
thicknesses, and differing very much in position; for sometimes they come cropping or "basseting" right out of the earth's surface, at others sinking far below it.

It is worth while noting the different appearance presented by workers at the several iron-mines, for that will tell us the nature of the ore below. Those whose business is with the "argillaceous" or clayey ironstone of Derbyshire, for instance, look as dingy and black as the men working in coal-pits; while those employed about the shallow or open mines more nearly resemble our ordinary railway navvies. But if we are in the hematite districts, such as the Forest of Dean, Ulverstone, Cornwall, North Wales, or Ireland, we shall meet with miners not pleasant to look at—their clothes, faces, and hands being deeply stained and smeared with the dense red peroxide of the ore among which they are working. England is well supplied with these same valuable red hematites, ores rich in iron, and which are often smelted with poorer ores. There is the hard "specular," or "iron glance;" the dull "kidney," found in Cumberland; the "micaceous," met with mostly in South Devon. Even

the intense red ochre, from which the red, yellow, and brown ochres and umbers in our paint-boxes are prepared, are but clayey members of the great hematite family.

The poorest of these ores are the "clay ironstones," such as are found in abundance in South Wales and Staffordshire; yet they are very important, as they furnish nearly two-thirds of the yield of British iron. Being closely connected with our coal-formations, they are worked cheaply, because of the plentiful supply of fuel and limestone near at hand. The most useful and valuable of their varieties is the common "black band," which, being extremely bituminous, can be easily calcined without fuel.

Among the finest kinds of iron we should have given the first place to the magnetite, or magnetic iron ore, such as is smelted with wood in the mines of Danemora, and of which



THE LARGE BLOCK OF IRON OF THE ISLAND OF DISCO, WITH THE CHAINS THAT SERVED TO TRANSPORT IT TO STOCKHOLM, WITH FIVE OTHER BLOCKS OF SMALLER SIZE. (*From a Photograph.*)

the Sheffield cutlers make their best steel knives, razors, and sharp instruments. This ore, which is found in immense masses in some parts of the world, forms the substance of hills, and even mountains. In Canada it occurs in irregular beds of considerable thickness, while in the vicinity of the valley of Andonirac it occupies a space of twenty miles in length by one broad. In our own land or in France it occurs but very rarely.

There may be several beds or seams of iron-ore lying one below another, but the merits of each is well known to the miners, who speak of it by a distinctive name or odd local designation, and these beds of ore are often separated from each other by masses of different minerals. When the "raw mine," or ironstone, has been "blasted" or loosened by means of gunpowder from its place in the bed where nature had tucked it so snugly, it is brought up to the surface of the earth, piled on low hand-carts or trolleys, and carried away to be roasted. This used to be always done by first burning the stone in the open air, but now it is generally dropped at once into the tall blast-furnace.

While it was the invariable practice to "roast" the stone before putting it into the furnace, the neighbourhood of such a place presented a more desolate appearance even than it does now, for there were always great rough heaps of dark cinder-refuse and slag to be seen in every direction. The roasting took place in the open air, to effect which unsavoury cookery a huge layer of "raw mine" was piled upon as large a layer of coals; then more ironstone, then more coals, and so on, until the tall pile rose some six feet high; the whole was then closely covered and packed in with a thatch of wet small-coal, to keep up the heat. When this edifice was completed a fire was lighted at one of the lower ends; this, I need not tell you, soon spread and gathered strength, being allowed to burn slowly for some time, roasting and decomposing the ore, and drawing out the sulphur and water contained in the mass.

Perhaps the question here suggests itself, "Why does smelting remove the impurities which are always mixed up with iron-ore?" Chemistry tells us it is through "affinity," or a tendency certain things have to combine with each other. Thus the lime and clay contained in this rough ore have, as we may say, a greater liking or affinity for each other than for the iron they are with; therefore, if the ore be of the usual clayey kind, the smelter adds a certain proportion of limestone to it; but if the ore be a calcareous or limy sort, such as that abounding in the Forest of Dean, for instance, he adds clay as a flux, or filter, to help the flow of liquid iron from the raw ore which contains it.

When timber was plentiful, and the uses of coal almost unknown in England, such ores were, of course, always smelted with charcoal, as most of them still are in countries where wood abounds and is the principal fuel. Of course nothing could be better, as far as the quality of the metal produced is concerned; but in these busy times, when so much iron is needed, and so many furnaces burning, our trade in iron and steel would come to a sudden standstill were it not for the coal and the coke that aid our ironworkers to get through tasks so much more rapidly, yet at a far lower rate, than of old.

To see the great change that has taken place in this wide-spread industry, let us go back to those good old times and our now busy "Black Country" (so called, let me remark, not from its dinginess, but from the supply of "black-band" ironstone which spreads in every direction). At the time I would return to, all this part of England was a little-visited but pleasant green wilderness. In its woodland recesses hid the forest deer, while here and there sheltered a hamlet or village where dwelt a few peasants, wood-cutters or weavers mostly. If there was a convenient stream or a commanding promontory near, there would most likely stand a monastery or a castle, of which we can view the remains, for if we visit our midland counties we shall find that they form the very centre of a busy hive of industry; yet in the densest and dingiest of the busy districts we shall meet with the bare grey ruins of many an ancestral hall, and among others, that of the Dudleys, whose domains extended far and near in those old days, when they were surrounded by a thick and pleasant woodland, musical with the songs of birds; now the neighbourhood is noisy with the clang and rattle of machinery, and dark with the smoke of tall chimney and gloomy furnace—true signs of the change of the times.

Yet in the days when these lords were so powerful, and the neighbourhood so lovely, all was not as pleasant as might have appeared in the fair midland counties. There was

too often feud and lawless raid among the barons. Thus we hear of one bold Dudley starting off on a dark night, at the head of a hundred and forty vassals and followers, armed with forest bills, long staves, and bows, to surprise and drive off their unsuspecting neighbours' possessions, in the form of many kine and sheep and right fat oxen, which were captured and driven in triumph to the stronghold of the Dudleys. No doubt there was fine feasting on the return of the venturous company, and that many a sheep and mighty joint of beef was cooked on those huge hearthstones which we now survey with wonderment. What grand old times these must have been, when those took all who had the power; but also what exceedingly miserable times for those who were not able to keep their own from the stronger hand uncontrolled by law, justice, or humanity. I much prefer thinking of a later period, when the lords of Dudley lived more peaceful lives, and obtained steadier revenues from the iron-mines lying in every direction, and yielding any quantity of ore, for which there was a steady demand.

But now a great drawback began to appear and to threaten the future prosperity of the owners of the mines. The ores must of course be roasted and smelted before they could yield the iron hidden in their depths; and wood, the only fuel then known, was becoming yearly more expensive and unattainable. These districts, lately so luxuriant with every kind of timber, were gradually assuming a bare and desolate appearance, and it seemed not only possible, but probable, that the flames of those craving, ever-hungry furnaces would some day have to be allowed to die out for lack of fuel; though, once extinguished from such a cause, who could say whether they would ever be re-lighted, or what use or profit could possibly be made of the abundant ore, which already gave employment to many, and constituted the treasures of its owners. About the time when this stern possibility began to make itself very obtrusive, the then peaceable lord and master of this rich domain had a kinsman known as Dud Dudley—a "man with eyes" evidently, for it appears that he was among the first who, thinking the matter seriously over, and considering what preventive or remedy might be applied, was struck with the idea of utilising in some way the despised coal that lay in rich abundance but all neglected and valueless under his feet. He at length proceeded to test this new fuel in the furnaces which had hitherto been fed only with charcoal, but as he did not understand the right way to burn it, and as the furnaces were not properly adapted for its use, the ore refused to melt, and the coal proved a failure, even though Dud Dudley, persuaded that his idea was a good one, spent over forty years of his life and a great deal of money in attempting to perfect it. He was an unfortunate man who never lived to see the success of his great discovery, which only seemed to involve him in trouble and expense. Folks treated him as though he was more mad than sane for attempting such a thing as smelting iron with coal. His experiments were openly mocked at and opposed, especially by the master charcoal-makers, who dreaded lest, in case of success, their hitherto flourishing trade should be ruined. Then, too, he became involved in the great civil wars of the period, and had other things to think of, for a long time, being harassed by many political and private enemies. Finally, when again at liberty to re-commence his smelting experiments, they produced but a very poor result. The furnaces he constructed being much too small for

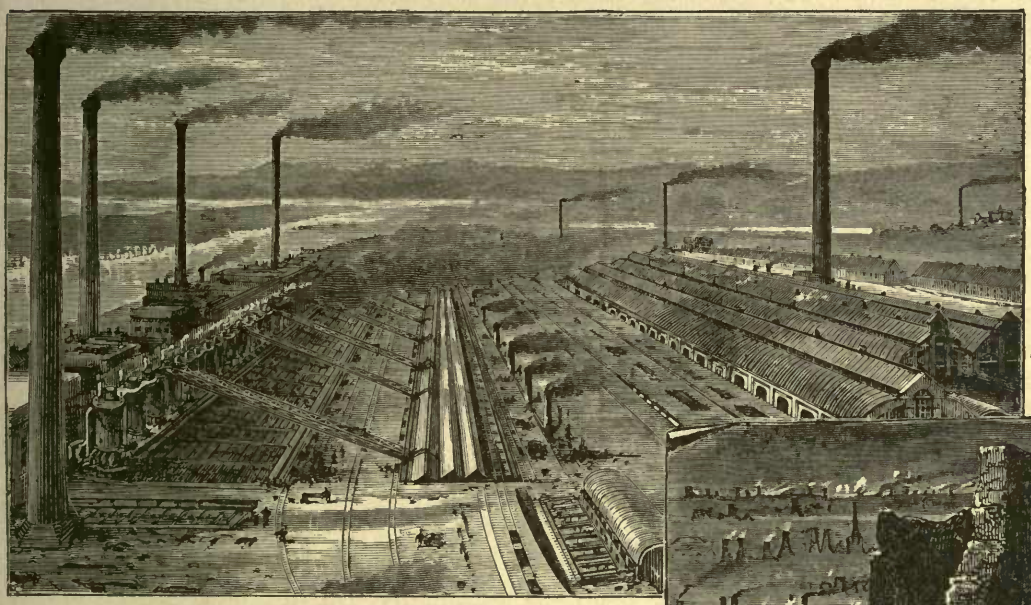
his purpose, the crude sulphur contained in the coal was brought into direct contact with the ore, which so injured the iron it fused as to render it of little use, and the thing was pronounced a failure. Wise "men of metal" declared nothing but wood-charcoal could smelt properly. But when this could no longer be obtained in anything like the necessary quantity, the production of English iron grew less and less, and before long supplies of this metal had to be bought of our foreign neighbours at a high price, though it lay scattered about England in every direction. Thousands of pounds were spent in purchasing iron of the Russians, and especially of the Swedes, whose preparation of this ore has always been, and is, yet unrivalled.

Yet Dud Dudley had set the ball rolling, though he had failed in producing the desired result. Others learnt the lesson his failure taught. The plan of smelting iron-ore with coal was tried first by one, then by another, and the result was the success of the famous iron-works at Coalbrookdale, in Shropshire. It was a lovely place still, surrounded with luxuriant timber-trees which were fast vanishing in the furnaces, when Abraham Darby, an ironworker from Dudley, seeing what was going on around and the ruin threatening English trade, determined if possible to work out that problem which had cost poor Dud so much time and money and trouble long ago, although he had worked in a district particularly suited for his purpose if he could have carried it out, for there was to be found every necessary—iron-ore, coal, the limestone for flux, and even the refractory fireclay required for the construction of the brickwork of the kind of furnaces he should have built, a clay now so valuable that it is employed all over the kingdom for the making of "pots" in glass-houses, crucibles for cast steel, and other industrial purposes.

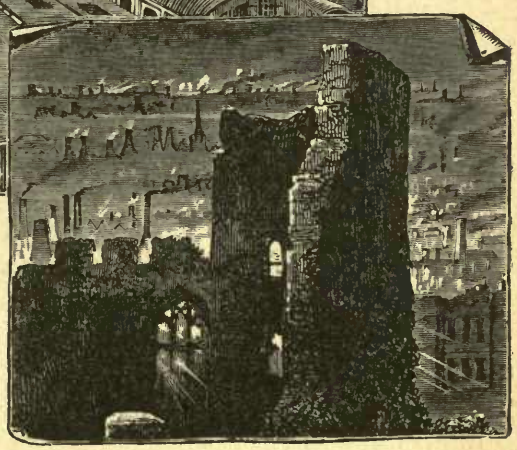
Darby, who was a Quaker, and evidently possessed a settled determination to spare neither cash nor trouble, had, no doubt, the great advantage of going on where his unlucky predecessor left off; at any rate, he and his at length read the riddle, and managed at last to smelt their ores properly with coal, or rather coke, which soon caused steam-power to blow the fires with its mighty breath, and lend that aid which was to make the British iron trade of such great importance to the world. Then another wonderful stride in advance was made in this great industry, when in 1826 a clever Lancashire worker announced the possibility of quickly and thoroughly converting pig or rough cast-iron, such as we have seen lying in its sandy bed, into good malleable wrought or bar iron, the preparation of which had hitherto been such a slow process that only about ten tons could be turned out weekly, where thirty years later, by means of this same ingenious Henry Cort's inventions and improvements, over which he spent £20,000 in perfecting, 10,000 tons were produced annually. Up to this time a great deal of money had been paid for such iron to those foreigners who, afflicted by no lack of charcoal, were able to supply it in abundance, though at a very high price, more especially in war-time, when it was most required. It was slow work, for until now such iron had been hammered at the rate of twelve hours for thirty hundredweight; now by means of grooved rollers, Cort's invention, workers can manufacture some fifteen tons in the same time.

But next came the same clever man's great invention of "puddling," that curious

process we saw carried out in the reverberatory furnace. It was easy to understand that in this, as the pig-iron, whatever its quality, received no fresh impurities, but left its own behind and came out malleable and good, the very great advantage of the process must be that inferior ores, such as are found in Yorkshire and other places, could be profitably worked, though they contain phosphorus, sulphur, and substances that cannot be completely burnt out of them in the furnace, or otherwise disposed of. Next came another step. We cannot help thinking it seems as though all inventors



BARROW-IN-FURNESS IRON-WORKS.



DUDLEY BY NIGHT.

must have learned to ignore the meaning of the words "impossibility" and "impracticable," by which most of their grandest inventions would have been nipped in the bud had they accepted them as conclusive verdicts, not always given by merely ignorant people, but by those who found it easy to settle a difficult matter with a big word. And yet, however, we can scarcely wonder at the incredulity of the "iron" public when one among them stood forth and gravely proposed to convert pig-iron, such as we have described it, into fluid, malleable metal, and to do this not only in a few hours, but without the expensive aid of additional coal.

This did seem really both "impossible and impracticable," for all the heat of the iron-workers' many furnaces had as yet only succeeded in rendering the said pig soft enough to bear hammering into shape. Here I must explain, in as straightforward a fashion as I know how, something concerning iron, that, as we have seen, comes from the blast-furnace in a highly-carbonised and impure state, which must be completely changed; this cleansing is effected by the singular puddling process, the decarbonisation being

caused by the exposure of the heated metal to atmospheric air, for the oxygen in which the carbon has a great affinity. This has often been demonstrated by the simple experiment of tying a large nail to a string, heating its tip until it is white-hot, and then whirling it rapidly round. As it flies it burns and brightens, scattering a circle of sparks, which show that as it meets the air combustion is taking place rapidly. We can also see this same process going on if we watch the blacksmith at work at his forge, where, as he hammers his horseshoes, he forces a powerful blast of air down into and on to every particle of the glowing metal he is banging into shape, while it is thus receiving a greater heat than he could expose it to in any other way.

Mr. (now Sir Henry) Bessemer's idea was simply that of using this same air for the double purpose of removing the carbon and increasing the temperature at one operation. He proposed to convert pig into malleable iron, "by forcing into and among the particles of a mass of molten iron, currents of air or gaseous matter containing, or capable of evolving, sufficient oxygen to keep up the combustion of the carbon contained in the iron till the required conversion is accomplished." Here you have his plan in his own plain words, which I think the youngest of my readers can understand.

The great difficulty for a long time was to know how far this process of decarbonisation could be carried. Many experiments failed; though, at last, when success was attained, it proved to be a discovery of the greatest value, as a sort of semi-steel can now be made suitable for boilers, roofs, railway lines, and other objects at the cost of about one-fourth of the cast-steel formerly used for these purposes, and far more durable than ordinary iron. In one year the Bessemer works produced over 900,000 tons of steel ingots, and 600,000 tons of nails, which fact shows the value of the invention.

But perhaps it is time to leave our explanations concerning the Bessemer steel, and take you into the huge works at Barrow-in-Furness, where you will see it in almost any quantity, especially in the form of rails of various shapes, "converted metal" having almost supplanted the old-fashioned iron for this particular purpose, as it is found to last six times as long—no slight matter in a country that boasts of having *twelve thousand* miles of railway, and that in the year 1877 exported 234,000 tons of these rails to other countries.

As we enter one of these extensive workshops, we shall be bewildered by strange sights and sounds. Men surely of a salamandrine breed, for they mind neither heat nor glare as they "round about the caldron go," working rod in hand in the large circular pits sunk deep in the ground, and round which are placed a number of iron moulds, lined with some kind of infusible clay, to prevent their being destroyed at once by the seething contents of the "converters," which will presently be poured into them.

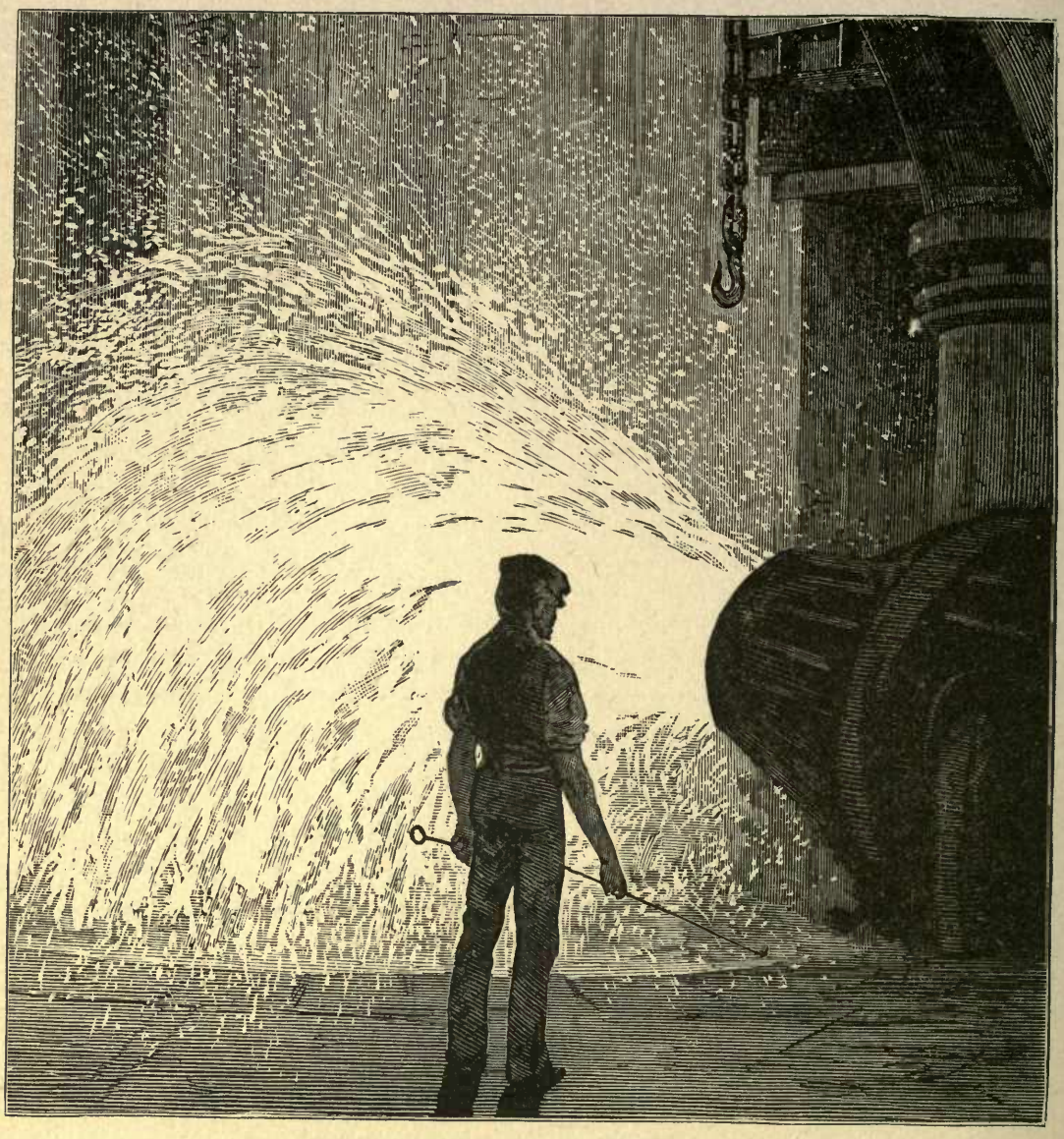
These movable converters, of which there are two to every pit, above which they are raised, are huge oval vessels, which can be swung about somewhat in the fashion of cannons. Until of late, they were filled with a mixture of molten pig and "spiegeleisen," or Swedish metal, prepared for them in cupola furnaces; but now the iron comes direct from the blast-furnace where it has been fused. To receive this flow the converter is tilted at a certain angle; when the molten supply stops, the huge pot is swung up again into a horizontal position, and the converting or blowing begins, noisily enough. For now a tremendous

blast of air is forced up into the seething contents of the vessel by means of holes and "tuyères" at the bottom of it—such a puff of wind as only a set of engines representing the united strength of 5,000 horses could produce. The result is something wonderful. But I must quote Mr. Bessemer's own description of this strange cookery:—"When the process is brought into full activity, small though powerful jets of air spring upwards through the fluid mass. The air, expanding in volume, divides itself into globules, or bursts violently upwards, carrying with it some hundredweight of fluid metal, which again falls into the boiling mass below. Every part of the apparatus trembles under the violent agitation thus produced; a roaring flame rushes from the mouth of the vessel, and, as the process advances, it changes its violet colour to orange, and finally to a luminous pure white flame. The sparks, which at first were large, like those of ordinary foundry iron, change to small hissing points, and these gradually give way to specks of soft bluish light, as the state of malleable iron is approached."

A weird sight, before which most dazzling fireworks would fade into insignificance. After this mighty blowing has been going on for some time, the "spiegeleisen" is added to the molten iron, and the whole mixed and mingled and combined thoroughly by means of the mighty blast. When at length "converted" enough, the liquid is poured into a monster ladle, which in turn drops it into the many moulds, where it soon cools into solid ingots of cast-steel, which we next meet with on low trucks, which boys are wheeling off to be re-heated in gas-ovens, and delivered over to the tender mercies of monster steam-hammers, or, more likely still, to be squeezed in the rail-mills, whence, after many struggles, the flat solid block of white-hot metal will emerge in the form of long and thin bars ready for home use or exportation.

This thriving neighbourhood of Barrow, like Cleveland-by-the-Tees, is an illustration of what a magic change industry and enterprise can effect in a place. Until the last few years it was a poor, shabby fishing village—pretty enough, but unvisited, and almost unknown. Its scattered and illiterate population of some 300 people earned a scanty livelihood mostly by fishing; their tumble-down houses showed signs of neglect and poverty; nothing of interest could be seen near the place, with the exception of the ancient ruin of an abbey, whose long-passed inhabitants must have led a most solitary life in the "once upon a time" when they flourished in this out-of-the-world spot, which, bounded east, west, and south by the sea, was then almost cut off from the rest of the world, giving as little promise of ever becoming the home of progress and prosperity as could well be imagined, even by the most sanguine. Yet this rural spot has changed so completely that surely the good monks of St. Bernard, could they peep, would never recognise it. Broad streets, comfortable, substantial red houses, fine docks, and the busy hum of a thriving population, reckoned to be of over 40,000 souls, have taken the place of solitude and silence; and all this strange and unexpected change has been brought about by the discovery of immense supplies of iron-ore—the very red hematite we have seen cooking by hundreds of tons at a time (the annual consumption is over half a million tons) in the furnaces of the great Barrow works.

Not that the iron-works were of much importance when they were first commenced. Some twenty years ago there were but three blast-furnaces where now we count sixteen, and these only attempted to melt the crude ore and produce pig-iron, while now they turn out



BESSEMER STEEL CONVERTER.

endless rails (one little order we heard of was for 10,000 tons of English steel rails, required for the New York Central Line), and plates of metal for ship-building purposes. Later on it was discovered that the hematite found in the neighbourhood was particularly free from phosphorus, and therefore well suited for conversion into steel by the Bessemer process. The result of this was the formation of a large company, and the building of the Barrow Iron and Steel Works, such as you see on page 63.

I trust that by now I need not point out that the long row of solid circular buildings on the left represent smelting or blast furnaces. Those long strips extending in front of each furnace are, as you guess, not the gardens they appear to be, but straight

stretches of sand, which form the beds on which the fiery sow and her litter of black, white, and grey repose when the different "floors" are tapped. As much as 5,000 tons of this indigestible kind of pork has been turned out of these beds in one week. At these works all the trucks containing materials required for fusion are carried, or rather drawn, to the top of the furnaces by means of winding engines, which take them up those slanting bridges to the opening in each bell-shaped furnace (which are here covered in), and, swiftly tipping the load of ironstone, flux, and fuel into the receptacle, send the empty cart sliding down for more, the demand and supply apparently never ceasing.

Those solid square buildings at the back of the premises contain the wonderful engines which produce the blast—their work is equal to 4,400 horse-power—and further back still is a long tube containing the supply of hot air that works the furnaces. Beyond are terraces of boilers, which supply the engines with steam. These boilers are not heated with fuel, but with the various gases produced by the fusion of the different materials which we know are being constantly poured into the blast-furnaces, which gases pass to the boilers by means of pipes, and carry immense heat with them. In all such large works as these, economy is studied in every detail, and no expense is spared in insuring it.

Now concerning steel, which, as we know, is merely iron treated with carbon in a peculiar way, yet differing from it in being much tougher, and possessing a far greater degree of elasticity, as when properly tempered it can be bent almost double. This is what has made it so useful for the various blades our Sheffield cutlers fashion. This flexibility also makes it invaluable to the steel-pen maker, who uses thousands of thin plates, which he cuts into narrow strips and stamps into shape, and for the numerous details of watches, clocks, and machinery. The "hair-spring" of a watch affords the best illustration of the value that *can* be given to a small piece of steel by manual labour, as 4,000 hair-springs, though weighing scarcely more than an ounce, may cost nearly £1,000. The tiny pendulous spring of a watch which governs the vibration of the balance costs a few pence, and weighs about $\frac{3}{10}$ of a grain; yet enough raw material to make many thousand such springs can be bought retail for the same few pence.

Wonderfully small and ingenious things have been made out of this unpromising-looking metal. For instance, we read of a tiny padlock made a hundred years ago by one James Lee, which, with its key, did not weigh as much as a silver twopenny-piece. The same man also made an iron lock and key that together were lighter than a silver penny. Mr. Chubb, of "lock" celebrity, exhibited a patent "Detector" set in a ring, the lock and key weighing sixteen grains; and in the Exhibition of 1851 there was shown a four-lever padlock only $\frac{3}{32}$ of an inch in diameter, the work of two clever boy workers.

If we ask what steel is, wise folk seem somewhat puzzled to explain, beyond that it is a combination of iron and carbon; but so is cast-iron, and so is even wrought-iron. All in different proportions, certainly, yet the principal difference seems to be in the manner of their combination; but as that is a puzzle which I could not explain or you understand very clearly, we will leave it alone. Steel has qualities peculiarly its own, and is made from bar-iron by the very peculiar process of "cementation," which was first heard of in England about the middle of the last century, and which soon effected a total revolution in, or rather re-created, the cutlery trade, for which Sheffield has ever been famous.

The bars intended for first-class cutlery steel should be of the best brand of Danish iron, or if for ordinary purposes it may be mixed with some best English wrought-iron. The prepared bars are taken to an odd-looking conical building called a "converting furnace," in which there is either one or two deep openings or receptacles, with fire-bricks so placed that when a fire is lighted the flames may be able to beat all about the outer surfaces so as to keep their contents at the high and regular heat upon which the success of the baking depends. At the bottom of each of these trough-like ovens is first scattered a layer or bed of powdered charcoal, on which is placed a row of the short iron bars which are to be transformed into steel. On and about these another layer of charcoal is scattered; then more bars of iron placed; then more charcoal, until the trough is full. The surface of the whole is next plastered up with a kind of cement, intended to prevent the charcoal from burning away. A fire is now lighted which is to keep the whole in a glowing, red-hot state for some days, during which time the baking is carefully superintended by an experienced worker, who every now and then draws out a "test bar," from the appearance of which he can judge of the exact progress of the rest. This he has to watch very closely, as steel for different purposes requires a different amount of conversion. For instance, that which is intended for knife-blades and cutlery does not need to be "treated" quite as much as that used for fine files. But if the steel is intended for objects to be afterwards cast in a fluid state, it must now be heated to a very high degree indeed. Altogether this part of the work necessitates great care and judgment.

At the required point the fierce fires are stopped, and the ovens allowed to cool slowly. When they are opened and the bars taken out, they will be found to be all over blisters, like wood which has been lately painted and then acted upon by the sun. These bars have absorbed a small quantity of carbon, and are no longer iron, but "blister-steel;" and as at its first stage blister-steel is not considered fit for anything but the very coarsest work, it has generally to go through other preparations, known as shearing, double shearing, or casting, which we will try to describe. This last process has only been in use for a comparatively short time, and is the one to which we owe the beauty of modern steel, the best kind of which, such as is used for surgical instruments and engineers' tools, costs as much as £50 a ton.

Pieces of "blister-steel" are put into moderately-sized crucibles, or melting-pots, which must be composed of very hard and indestructible materials, as they will have to bear most intense heat when they are placed in a kind of invisible chamber or furnace which is sunk in the floor of the stone-paved casting-house, and kept closely covered in with an iron lid, which is lifted off from time to time that the worker may take a peep at its contents or add more fuel when required. This man must be very skilled and experienced at the work, for he will have to judge by appearances, unaided by any test, as to which is exactly the right moment for adding the mixture of carbon and manganese required to refine the steel, and also be ready to give the signal for removing the pot and its seething contents as soon as certain signs appear to his practised eye, the neglect of which would spoil the whole batch.

While the stew is getting ready, the worker places his cast-iron moulds ready for its

reception. These are not unlike long bullet-moulds, being composed of two halves, which are bound closely together, fit exactly, and their insides are coated with some sort of composition. Now they are placed—one end in a kind of hole in the floor, the upper end wide open to receive the contents of the pots. When the signal is given, the lid is lifted off the furnace, the fuel pushed back from about the white-red pot below, which a masked man then seizes upon with a pair of pincers and drags out of its fiery resting-place. Poor fellow! it is fearfully trying work, for he has to bend down and face the fearful heat burning and glaring beneath him. Then the lid has to be lifted off the crucible, and the liquid steel, about which float little greenish sparks, is "teemed" or poured straight down into the mould—an operation which requires the greatest care and the nerve which long practice at such a task alone can give. The pot is now to be again filled with bits of steel and returned to the furnace. When the casting is cool enough to bear removal, the two halves of the mould are unfastened and its contents turned out and prepared for the steam-hammer.

CASTING STEEL INGOTS.

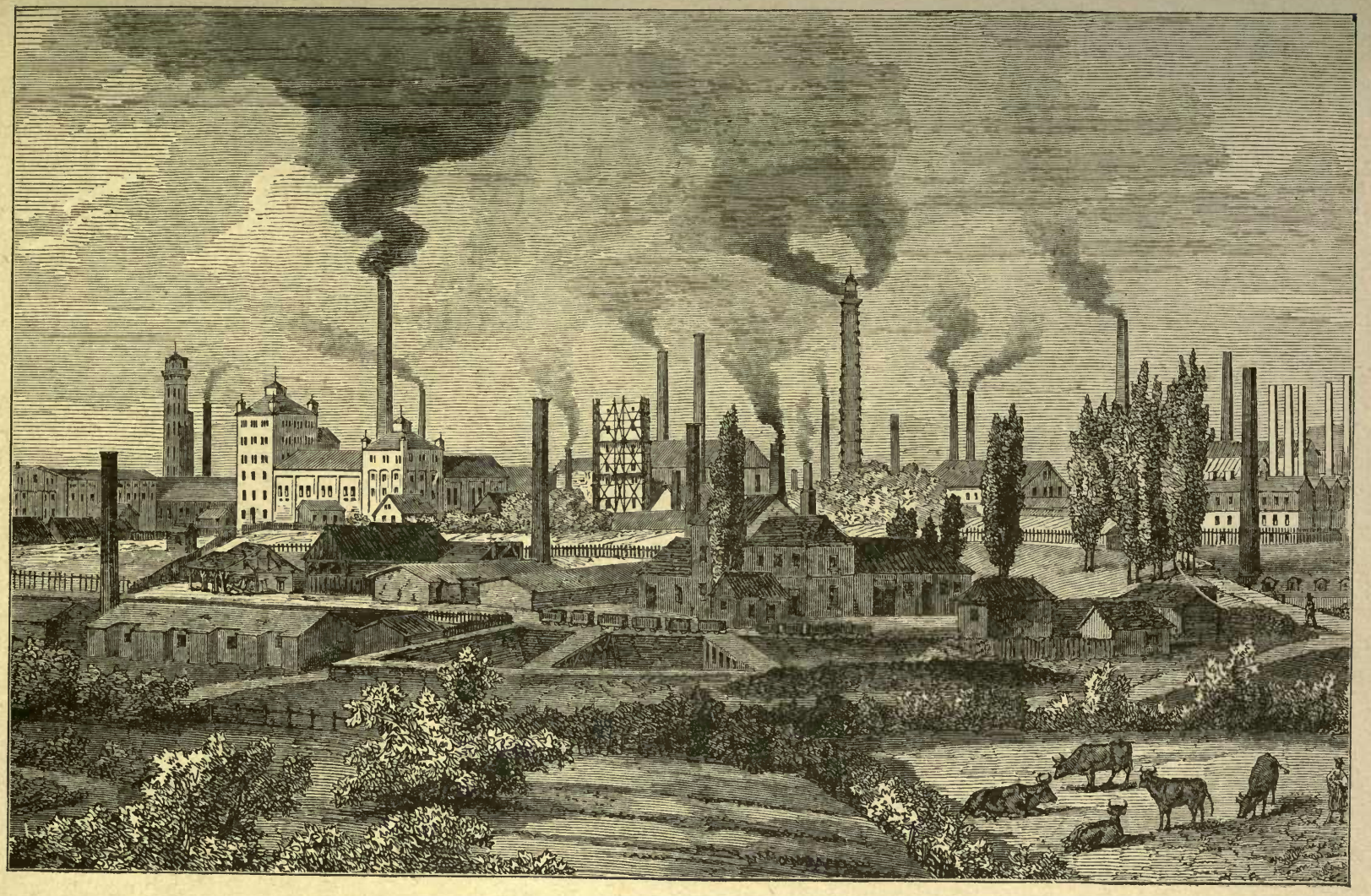
Manganese is a kind of metal which we meet with here, as we shall do in many other departments of our Wonderland, and is worth noting, for it is one of those things which, though known well enough by name, is otherwise generally ignored. Yet as much as 50,000 tons of it have been employed in Great Britain in one year; and no wonder, for we find its different oxides used in potteries, where, I believe, it is never employed in quite a pure state. It gives the dense black colour to certain kinds of opaque china and tiles; in glass-works it helps to clear flint-glass of impurities, or to tint it of a beautiful purple. It is employed in paper-making, and in the bleaching and dyeing of cotton, and to form bleaching-powder. It is of service in disinfectants, giving the peculiar pinky colour found in some of them (Condy's fluid, for instance); and, as we have seen, it is of value in the conversion of iron into steel by the Bessemer process. It is thought that its peculiar property of improving iron was known long since, and that the celebrated "Toledo blades" owed their pliability and excellence to the presence of manganese. Surely, knowing all this, it is worth inquiring what such a useful thing is and where it is to be found.

Large supplies of this hard though brittle metal are obtained from France and the mountains of Spain and Portugal, where it lies in scattered "pockets" near the surface of the ground. Here the miners find it in detached lumps and masses, which they collect, and pack and pile in panniers swung on their mules. These animals are then led down to the nearest streams, where their load is closely examined, sorted, and washed; the best pieces are again re-packed in the baskets, and a whole train of the plodding, sure-footed animals are led off, sometimes many a mile and over very rough roads, which no cart could cross, to the nearest seaport town or railway-station, where their pack is disposed of at a very low rate. A quantity was also found in different parts of Great Britain.

But to return to our old subject, and after having shown you so much concerning our English Wonderland of iron and steel, let us take a flight over the sea and away to Essen, a quiet part of Rhenish Prussia, where we shall find a very crowded hive, swarming with industrious and busy metal-workers of the most ingenious kind. Here is an immense establishment where not only almost all the German ordnance guns, their carriages, and projectiles are made, but also much that is required for more peaceful needs and interests—shafts, boiler and ships' plates, axles, tyres, wheels, springs, and engines. For here we are at Herr Krupp's famous works, where there are usually more than 1,000 furnaces blazing, not to mention hundreds of smiths' forges and steam-boilers, to keep all of which going we are told it takes more than 600,000 tons of coal and coke per annum. One hundred and eighty acres of work-buildings are roofed in, and as so large a place must be well lighted, the necessary gas has to be made on the premises, and sheds its glow from 20,000 burners, which, however, I am informed, are now being displaced by the electric light. Locomotives are flying about the works in all directions; and here are telegraph stations, from which we may send or receive messages from almost all parts of the world; here is a chemical laboratory as well as a photographic and printing department—all very useful in such monster works, where some 9,000 men are employed, besides a great number of extra ones busy at the mines beyond. In fact, the whole place represents an industrial town, where the workers' wants are well attended to by one great master spirit, for near by the ceaseless din and rattle of the forges are to be seen sundry model villages—"Krupp colonies"—places where the many workmen and their families are comfortably and cheaply lodged, where they can send their children to schools in every way suitable for them, and where there are several provision stores, flour-mills, bakers, and other establishments at which things may be bought at cost price. Altogether it is a most interesting place to visit, but it would take us so long to find out for ourselves all that is done there that we cannot do better than read what was lately written concerning it by one who had attended a trial of the great Krupp ordnance guns at Meppen, in Westphalia, and afterwards examined, with admiring curiosity, the details of this city of iron :—

"The Essen Factory offers a marvellous spectacle, both to the initiated and to those who have little knowledge of such matters. One of the more striking parts of the exhibition was that which showed the Bessemer process in full operation. Rivulets of fire and roaring jets of flame, mingling with myriads of star-formed sparks, constituted a display which might have suggested actual peril to the beholder, had it not been for the evidence of perfect control which was being exercised over these fiery forces. Bessemer steel, we may remark, has nothing to do with Krupp guns, but it is largely employed for various purposes, especially the manufacture of steel rails. In the Krupp works the metal is never allowed to become cool, from the time the ore is first melted until the rail is produced.

"The forging of a solid cylinder of steel under the great 50-ton steam-hammer was one of the marvels of the day. This mass of metal was intended to form the tube or interior of a 35½-centimetre gun, equal to a bore of 14 inches. The weight of the steel mass was about 30 tons, and its length about 30 feet. It was hauled out of the furnace in a state of incandescence, and was pounded under the giant hammer—the largest in the



HERR KRUPP'S FACTORY AT ESSEN.

world. This, moreover, was set up several years ago, and has been at work, more or less, day and night ever since, never having required any repairs, except of a trifling character. The ingot now subject to its power was beautifully controlled by means of chains connected with a steam-engine, so that it was turned round under the hammer without any visible intervention of the workmen. This hammer, we may observe, is able to give a stroke due to a fall of 12 feet, and the force of the blow is considered equal to 1,000 tons."

Passing on to another building, the visitor entered a "finishing-shop," where the final touches are given to the curiously-shaped masses of metal. Here were lathes, and slotting and planing machines, under whose powerful influence no metal could be obdurate. Iron and steel were cut almost as if they were wood, and one thing our observer noticed was the extreme clearness of the steel, resembling, in some cases, polished silver. "A single speck in a block of steel is held fatal at Essen, and such a product is at once rejected." In the next building was the largest "face-plate" in the world. This was an upright disk of cast-iron, 30 feet in diameter, and cast in two pieces. The plate was slowly revolving on its centre, while a species of plane was cutting its way into a curved rail, called a "racer," used in the traversing of guns, this curved rail being fastened on the flat surface of the colossal plate. Near at hand there were powerful machines at work boring the tubes for field-guns. One large building contained guns that were finished, one being "packed up" ready for departure. Great 12-inch guns were lying about as if they were ordinary commodities, and on emerging into the open air a field-gun was seen travelling aloft on a wire-rope railway. By means of this aërial line, light guns are transferred from one building to another on the level of the upper floors with extraordinary facility. An example of another kind was not far off. In the largest "finishing-shop" in the world—a lofty structure, literally big enough to build an ironclad in—was a 50-ton travelling-crane, stretching across the whole breadth of the building, and at a vast height from the floor. Under the same roof was another contrivance of a similar kind, designed to lift 20 tons. There was also a gigantic hollow lathe, made by an English firm at Leeds. There, too, was a wooden model on the full scale, of a 46-centimetre gun, to weigh 120 tons. Whether such a gun will ever be made I cannot say, but Herr Krupp is prepared to make it, and it is designed as a breechloader. Here let me remark that the Italian Government has lately had a 100-ton cannon made of cast-iron, at a cost of £9,000. Its interior is lined with steel rings, 450 lbs. of powder being required for each charge.

The visitor next proceeded to witness the casting of a 20-ton steel ingot. This is not considered a heavy casting at Essen; but the scene, we are told, was one to be remembered. Crowds of men were engaged in hauling up crucibles of molten steel from sunken furnaces, and emptying the contents into channels communicating with the casting-pit. The whole place seemed pervaded by subterranean fire; but the work was done quietly and efficiently, eleven minutes sufficing for the entire operation. When a really big casting has to be made, a thousand men or more are employed in the process, which may well be dubbed "terrific."

If we wish to compare our own Royal Ordnance Works with those famous ones at Essen, we had better hear something concerning big guns, and then pay a visit to Woolwich Arsenal, where another of the largest steam-hammers is to be seen at work.

Perhaps some of you may not be aware that most of the cannon of Great Britain are

made differently to those of Prussia, Russia, Austria, and France, who all use breechloaders—that is, the necessary projectiles are introduced in the rear, while, as regards most of our guns, we still ram them in at the muzzle. Then, too, unlike the Krupp cannon, which is of cast-steel, or the Austrian steel-bronze gun, and contrary to the French iron gun, surrounded with steel hoops, the Woolwich gun is fashioned of steel and encircled by iron hoops. They are marvels of strength—too strong and too large, some say, to be easily loaded, and the whole system is now being examined by scientific men. But taking them as I write, if we examine one of these "ministers of war," we shall see that its body is of steel, strengthened by cylinders of iron. Once it was a solid mass of steel—of the length of the required gun—costing perhaps over £400; because, having to stand the sudden strain of powder and shot, it had to be of the very best casting and quality, and its tight iron jackets of the toughest and firmest, especially about the vent, or "touch-hole," otherwise fearful would be the damage to follow when the firing took place.

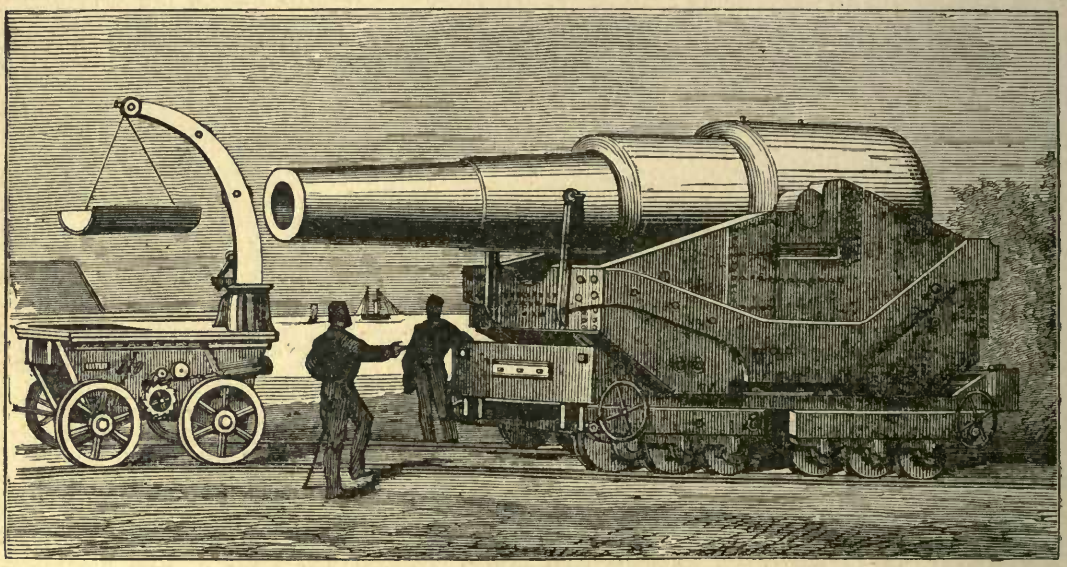
As we are getting to the end of our time, we will suppose the interior of the solid steel tube to have been already cleared out by a boring-machine, and that we are witnessing the "coiling process" by which those bars of iron are to be strengthened and prepared for the place they are to occupy about the mighty tube they are to protect from strain. To effect this, the huge bars are placed in a long furnace, built for this purpose, and are well turned and worked about until the metal is considered to have become sufficiently solid and fibrous. Then one red-hot end is seized upon by a revolving cylinder, which draws it out, and coils it round and round in a huge spiral ring, weighing many tons, after which it is left to cool, when it is ready to be forged or welded into a hollow ring or hoop, intended to be slipped over the steel body of the cannon after the manner of a bracelet.

But that is a tremendous job, which only a most tremendous "tool"—if we may so speak of the 38-ton hammer here employed—can effect. When the spiral of cold iron, once more heated until it is white-hot, which perhaps it takes two days to effect, is ready, it is given over to be welded by this monster hammer, every fall of which, aided by steam of course, represents a weight of almost 1,000 tons. But before the coil, which may weigh from 20 to 40 tons, can be thus hammered into toughness, it must be somehow dragged from the fiery recesses of the furnace which contains it. In order to effect this, a pair of tongs—*such* a pair of tongs—are needed, and experienced handy workers to manage them. A dazzling, wonderful sight is a "heat" or opening of this furnace at the Woolwich Arsenal, though beforehand it appears to be a huge black blank, for every crack and crevice has been carefully "luted" or stopped with wet fireclay, and no one not forewarned could possibly imagine the weird sight to come. A sort of general flutter takes place; the broad anvil is brushed; the huge hammer gives a sort of convulsive lift or two, as though to try its strength; the dozen half-naked men stand ready, while the clay is quickly picked out; then comes the slow lifting of a dark door, weighing 8 tons, and the burst of such a mighty glare of light and heat that it is difficult to tell what follows, and we turn away half-blinded, but with the conviction that surely there can be nothing but flame within that fiery oven.

Those eager workers know better, and fling in wet sand, which, darkening as it falls, shows them the metal they are in search of. Once having ascertained its position, the heavy

tongs are swung, and soon clinch fast and drag it forth, dripping with fiery and streaming metal. In a very short time it is placed under the hammer, which beats and batters the huge morsel changing to all sorts of colours under its heavy taps, which only stop for a time, to re-commence when a coil or bolt of cold iron has been slipped into the cylinder, and driven right through its centre, leaving it hollowed, and of the shape required. When the coils (four of which are usually required for one gun) are so far ready, they are placed in large steam-lathes, and pared and made smooth, their inner sides being carefully gauged that they may fit the places they are to occupy.

But now for the last process. Of course you know that all our modern guns are "rifled"—that is, have furrows running along the interior of the steel tube. This rifling is accomplished when the cannon is otherwise finished, by cutting in its interior a



THE EIGHTY-TON GUN.

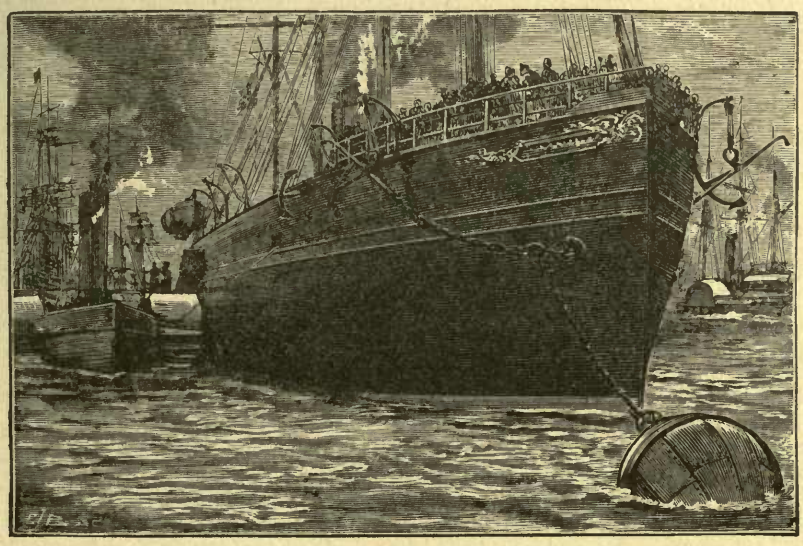
series of grooves, into which the studded surface of the shot (which now much more resemble sugar-loaves than cannon-balls) will fit, flying out with far greater accuracy than when discharged from the old smooth-bores; for this spiral rifling gives to the ball a rotation which is rapid in proportion to the force of the explosive and the sharpness of the twist in the spiral, the revolution of the ball on its own axis keeping that axis, gravity excepted, in the line in which it leaves the piece, so securing that thorough correctness of aim which is so indispensable for attack or defence either on sea or land.

And now let us turn to something that saves instead of destroying life, and give honourable mention to the sturdy and patient anchor-smiths, the regular "bing, bang, bing!" of whose hammers is to be heard afar off as they fall on a red-hot mass of glowing metal, soon to be transformed into a mighty

"Anchor whose giant hand
Will reach down and grapple with the land,
And immovable and fast
Hold the great ship against the bellowing blast."

A perilous business truly, and one upon which many a precious life may depend, so we need scarcely be told that only the very best scrap iron is used for the purpose of forming the "giant hand," as also for the many chains and cables that hang about and restrain every vessel. Very much of this iron comes from South Staffordshire, some 70,000 tons being annually used in the Black Country for such objects alone. The scrap iron having been beaten and banged into big solid slabs, these are placed in numbers under a heavy drop-hammer, and then forged and finished by hand—no slight work when the anchor is to be a large one, for they vary in size from the fisher-boat's little grapnel to that required by an ordinary sailing-vessel, or such a huge one as that made specially for the *Great Eastern*, which weighed 8 tons. At best it is a hard and trying task, as the smith must rush at the great glaring mass of red-hot metal, and strike his blows swiftly and surely, before it has time to cool; but the heat is so intense, and the big sledge-hammer so heavy, that the poor fellow can but let it fall once, and then hastily retreat amid a shower of sparks and make room for his fellows, who step forward in turn, their successive blows causing that regular and almost musical peal which at first so pleased our ears, but at last threatens to deafen us.

Not only are anchors made of the best tensile iron, but, for "the better security of lives and property afloat in sea-going ships," they must be thoroughly tested by hydraulic power used by properly-appointed persons, who, after carefully examining the different parts, will give an official stamp declaring it as safe and sure a piece of workmanship as strong arms can fashion.



AN IRON KING ABOUT TO SAIL OUT OF THE THAMES.

"A vessel as goodly and strong and staunch
As ever weather'd a wintry sea."

"STITCH, STITCH, STITCH."

"THE TOY-SHOP OF THE WORLD."

E find that it was written as long ago as 1538 that "in Bermigham were many smiths and cuttlers, that make knives and all manner of cuttynge tooles, and many loriners that make bittes, and a great many naylors. They have their iron and sea-cole out of Staffordshire." And later on we read also how one manufacturer of "cuttynge tooles" readily supplied the forces of the Earl of Essex with 15,000 swords, while the Royalist party were not only refused blades, for which they were willing to pay, but those who would have supplied them with the much-needed weapons were ill-treated and imprisoned by their fellow-citizens.

In these our days, "Bermigham," though it still makes weapons, is now no longer specially a town of cutlers and smiths; that distinction belongs more properly to busy, grimy Sheffield and that neighbourhood. Its workers excel now more particularly in the production of endless varieties of fancy metal articles, ornamental or useful. Burke christened it "the toy-shop of the world." Lead, tin, brass, or even silver and gold, are aptly worked up by their dexterous fingers and wonderful tools and appliances into every possible thing which metal can form, from a dozen shining buttons for your brother's jacket to a thousand English axes ready for exportation, from sleeve-links to chimney-clock cases. Stamp and die are for ever at work. Labour, skill, and time—the men of Birmingham will give all to accomplish any task they have in hand, and more honour to them for it.

If we peep in and about the smoky hive of workers we shall see its bees busy at all kinds of work, producing a thousand and one things which, though we find it difficult to

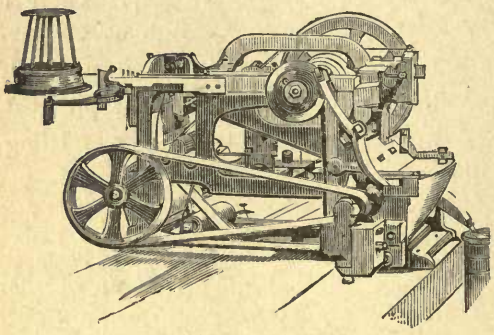
remember, we should sadly miss if the supply ran short. Here are workmen's tools, soldiers' weapons, ladies' implements, such as thimbles, pins, needles, buttons, scissors, penknives, or studs, screws, saddlery, shining electro forks, spoons, teapots, cruets, and trays, thousands of boxes of steel pens and their fancy holders, elaborately plated pencil-cases, papier-mâché boxes and oddments of many kinds. As to cheap "Brummagem" jewellery, watches, chains, rings, and brooches, their name is legion. I cannot attempt to number the varieties it supplies for home and foreign markets, not to mention the handsomely chased cups our Volunteers are so proud of winning, or, less pleasant to note, the cutlasses, hatchets, pistols, bayonets, swords, or even ugly tomahawks, spear-heads, spiteful-looking daggers, useful woodmen's hatchets, and knives of the most treacherous order, which *may* be only intended to cut a harmless log, or a way through the jungle, or defend its wearer from wild beasts, but that would very readily serve for a less peaceful purpose, when once in the hands of some far-away savage who has bartered all his forest wealth to possess it.

We are among so many workers now that we scarcely know where to stop. There is not a pin to choose between them, their tasks are all so interesting. But, as we have mentioned it, let us stay at a pin. Yet what can we say about it? I had it so firmly impressed upon me when I was a child that it took twenty people to make one pin that, though I see it at work, I can hardly yet believe it possible that this noisy, rattling, snapping little machine can by any natural means turn out between 200 and 300 pins per minute, unrolling and snapping up, as fast as eyes can follow, yards upon yards of fine bright brass wire, great coils of which are hanging about us in every direction—hard and dry food for the little devouring metal monster before us, that gobbles it up quicker than seems natural to unaccustomed eyes.

Before fairly examining into the "how and why" of this wonderful little automatic machine, we are told that it was originally an American invention, but that very many clever persons have spent years in perfecting it into what it is. Just note—a pin-making machine! Really, we cannot help remarking that surely they might have employed themselves in a more profitable task, for, after all, what does it do? Makes a pin! But what is the value of a pin? If any lady wishes to express the worthlessness of an object, does she not say, "Oh, it is not worth a pin," or "I would not give a pin for it"? and yet here is quite a complicated machine invented for the sole purpose of making such things, and we are invited to admire and wonder at it all the more, as through its means England is the richer by a national manufacture of greater importance than we can possible realise while we consider only a pin as a pin. And here we have some wonderful commercial statistics quoted, which prove that for the benefit of self and neighbours—for English pins have a good reputation abroad—Great Britain produces about fifty million pins *daily*, thirty-seven millions of which are manufactured in Birmingham. Altogether, the trade in these trifles we scarcely thought worth mention is estimated at about £220,000—think of that!

When metal pins first came into use among the English ladies, which was somewhere about the commencement of the sixteenth century, being brought to our country by foreign traders only, they were expensive, and considered to form a very agreeable and acceptable new year's gift; but as they were not always obtainable, a sum of money wherewith to purchase them was sometimes more conveniently presented, even to rich dames, as "pin-

money;" and a wife's allowance of pin-money was thereafter often fixed and agreed upon in the making out of marriage settlements. This is alluded to in many old household documents. There seem to have been so many complaints concerning these first pins (I suppose the ladies did not get enough for their money), that in 1543 Parliament interfered, and passed an "Acte for the true making of pynnes," wherein it was decreed that they were not to be sold for more than six shillings and eightpence (representing about ten times the sum it does now) per thousand. This change from the old-fashioned clumsy bone and wooden skewers must certainly have been such a very agreeable one, that we can scarcely wonder at the ladies being at first somewhat extravagant in their purchases of them. During the early part of the reign of Queen Elizabeth it is said that not less than £60,000 were annually spent with the foreign merchants, who, as we know, imported these useful little accessories to the toilet. But before the end of her Majesty's reign, and during that of her successor, plenty of English "pynners" were found, whose fine work in metal "pynnes" excelled that of any of the foreign artificers, who hitherto appear to have had the flourishing trade all to themselves.

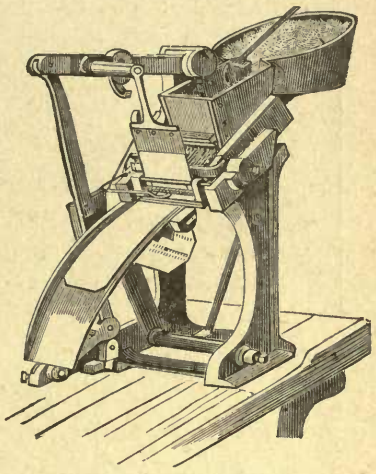


PIN-MAKING MACHINE.

Brass and iron wire pins are said to have been originally a French or Italian invention, though others think that they travelled over the seas from thrifty Holland, along with the useful and homely little thimble. However that may be, English "pynners" were regularly at work by 1542, as it is on record that they were forbidden by Act of Parliament to sell "any sort of pynne except such as shall be double-headed and have the pynne soldered faste to the shanke of the pynne," which looks very much as though exception had been made to the solidity of their wares. Yet the company must have prospered, and become wealthy, for when Charles I. was king its members agreed to pay him £500 a year for the advantage of certain privileges, which were afterwards confirmed by Charles II., who also bound himself to raise £20,000 for their benefit, to provide a stock of wire, and to take all the pins they made at prices to be fixed by the Lord Treasurer, the pin-makers undertaking, in return, to deliver 70,000 lbs. weight, not of pins, as one might expect, but of ordnance half-yearly to the Master of the Ordnance.

But to our own times and our own pin-makers. First let me remark that there are "pins *and* pins," from the doll or baby pin, so small and light that it can scarcely be picked out of the roll of fine white satin ribbon which it is often used to fasten, to the sturdy "corker" or "blanket" pin as long as your finger. There are the useful "short whites" and "mixed," for ordinary use and dressmaking purposes; there are long, fine wire pins, used by naturalists for transfixing butterflies and insects; and doubled-up safety-pins, so useful in the nursery, and which, I have heard, were first made in imitation of the sharp straight thorns which wandering gipsies ingeniously doubled and bent and twisted to hold their tattered shawls or other garments together. There are unreliable brass pins, which are sold at about fourteen pence a pound; and slim gilt pins, for natural history

collecting, which cost seven or eight shillings an ounce; and there are "long shawls," and numberless hair-pins, and mourning and other pins, which we may not remember just now, but the uses of which are worth considering, when we undervalue pins in such a wholesale manner. Quantities of pins are also made in France, Germany, Austria, and especially in America, where it is said that from 400 to 500 tons weight of these humble but useful articles are annually turned out, most of them to vanish nobody knows where. And we scarcely need be told that to make these numerous pins a very large quantity of metal is necessary. In England alone we use 2,500,000 lbs. of brass wire and 344,800 lbs. of iron wire annually. Then, too, there must be a great supply of pink paper and cardboard absorbed in the thousands of dozens of ornamental boxes in which "mourning," "nursery," and hair pins are usually sold. Altogether, it must be easy to believe that, after all, such an industry must be of importance, and that the little machine that can make pins at the rate of *millions* a day must be worthy of notice in our world of useful things and unconsidered trifles.



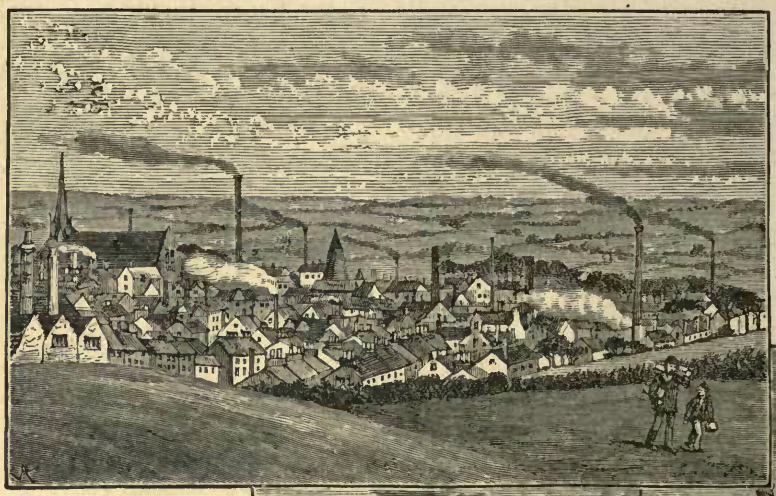
PIN-STICKING MACHINE.

Perhaps we shall wonder at it all the more, if we hear some one who knew all about it describe how the pins used by our mothers or our grandmothers were made. He says, "One man draws out the wire, another straightens it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head. To make this head requires two or three distinct operations. To put it on is a peculiar business; to whiten the pins, another. It is even a trade in itself to put them into the paper. The important business of making a pin is in this manner divided into about eighteen distinct operations, which in some manufactories are all performed by distinct hands, though in others the same man will sometimes perform two or three of them."

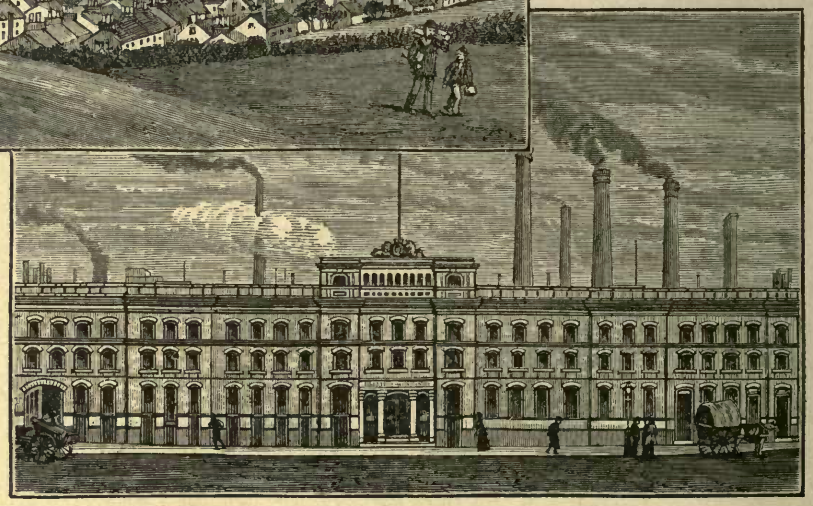
To-day the wire is transformed into pins at such a rate that it is really impossible to count them as they fall, or to describe very clearly what becomes of the wire during the short interval which elapses from its passing off the reel on which each ring of metal thread is hung. We can watch its end being first seized upon, then the curved piece is drawn out and straightened as it travels on to be cut; then a pin's length is pushed in and held fast by a kind of nipper, while an iron something snaps sharply down with a rap, and leaves the pin's length with a neat little head, yet a good solid one too, which will hold on, unlike those laboured over by the worthy "pynners" of old, that required two or three distinct operations to join them, and a practised hand to fasten properly on to the shank.

The bit of wire—for we cannot call it anything else yet, though it is provided with a head—is now snipped off its parent coil by a sharp cutting instrument, which runs down upon it with an indescribable snap; then away it slides, as though glad to be free, dropping off an incline into a kind of tray, where its straight shank will slip through a small slit, which allows the newcomer to hang helplessly by its head, which cannot conveniently pass through the opening. As it dangles here, in company with many others of its kind, the blunt ends of all these wires are sharpened by a revolving steel roller, which

bristles all over with vicious file-like teeth of various sizes and degrees; as this flies wildly round, it encounters the wires, and rubs and scrubs and changes the blunt ends it meets into fine points in a far shorter time than I have taken to describe this most ingenious process. As each pin is pointed, it is somehow instantly pushed on and out of the way by others that want attending to, and come rushing on at the rate of some half-dozen a second, each, as it is done with, falling into the receptacle which stands under the pointing roller at the end of the machine, and out of which we can easily pick a small handful and note how neat and thorough the workmanship of such a simple thing as a machine-made pin can be.



REDDITCH.



NEWALL WORKS, BIRMINGHAM, THE LARGEST PIN-FACTORY IN THE WORLD.

Yet, though they have just been made, they do not look quite like the bright, silvery new pins we buy. That, says the lad who "feeds" the machine, is because they are not yet "cleaned or coloured;" the machine only shapes them. They require whitening now, and to see this whitening process we must step into a small room where a peculiar kind of cookery seems to be going on, presided over by a "colourer." It is that of the innumerable shabby pins boiling in weak beer, which removes all the dirt and grease. They are next laid in a large copper vessel partly filled with alternate layers of pure grain-tin, and pins. When layers enough have been arranged one upon another, they are covered with water and sprinkled with cream of tartar, after which they are very gradually and slowly heated. In a short time we shall see a change coming over the contents of our stewpan, for the acid acting upon the tin produces "solution of tin," the peculiar property of which is to "colour" or "silver" the innumerable pins, giving them that pretty new look we missed so much just now.

When they have arrived at the proper degree of brightness, the newly-made points are washed in clean water, and dried and brightened in a "shaking barrier," or bag

THE SEMPSTRESS'S BEST FRIEND.

A STITCH IN TIME.

filled with bran, like a monster pincushion. Then the pins are collected in large boxes and carried off to the papering-room, to be weighed and folded up into neat little packets, fitted into boxes, or most likely stuck side by side in long rows on pink, blue, and yellow sheets of paper—an operation which once employed many children's busy fingers, but which is now the work of another wonderful little self-acting machine, which only requires the assistance of one girl, who feeds it with as many pins as are required to be "folded" for sale. All she has to do is to drop the shining supply into a hopper, which passes them to a steel plate with as many slits in it as there are to be pins in a row. The girl next proceeds to stir the contents of the hopper with a thing which looks very like a comb, and the shanks of the pins drop through the slits in the plate, and hang by their heads as we saw them doing when they were being pointed in the first machine. Then

the pink paper is neatly folded and crimped, and presented to the line of sharp protruding points. All the pins take their places in a straight stiff row, as though they were soldiers at a review, and this goes on so rapidly that before we can feel quite sure that one row is finished we are shown the whole array of twelve rows, consisting of 516 new pins, which will sell for about threepence in the shops. So much for the folding-machine. From first to last, the cutting, colouring, and folding of all these pins have employed three people, and they are all very much more to be relied on than those that it took eighteen or twenty pairs of hands to fashion, or those earlier ones still that were not on any account to be sold for more than six-and-eightpence a thousand.

Now concerning needles, which so naturally follow the mention of pins.

Needles of some kind appear to have been used in the far-away ages. Civilised or uncivilised folks have found out their use and value, and made them, all untaught, out of tiny bones and hedgeside thorns. In the British Museum we are shown bronze needles three or four inches in length (other smaller ones were made, no doubt), which did their work in the world long ages before that famous stone obelisk known as Cleopatra's Needle was raised in the far distant East.

It is believed that the first steel needles were made in the fourteenth century, when so many things began to be improved upon by the skilful craftsmen of quaint old Nuremberg, who were already known at that time for their "lateen," or metal drawings of iron, steel, or brass wires, long years after steel needles had come into use, and even when they were manufactured in England the steel wire of which they were made was always brought from Germany. It was a German who first taught Englishmen the art of making these now indispensable things, though the knowledge does not appear to have been thought of much importance. It was not until 1650 that a small needle-factory was established in Buckinghamshire, where this now thriving industry was carried on for many years. In a cyclopædia not thirty years old we read concerning needles that every "sewing-needle, however inconsiderable in size, passes through the hands of 120 different operatives before it is ready for sale." So that before machinery of one kind and another came to aid, needle-making must have been a slow and tedious task. Many poor women, young boys, and children were employed in it, and were miserably paid for the hard work they did, while the needles themselves were inferior and much more expensive than they are at present.

One especial part of the work reserved for lads was the eye-piercing. After father, or more often mother, had flattened the head by a blow from a smooth-faced hammer, each needle was passed on to a boy, often a very little one, who, placing it on a steel block, held the small point of a sharp tool downwards on the head, and gave it a tap on the upper side, then turning the tiny bit of steel, he dropped another blow immediately over the place he had just now struck. The needle was next pounced upon by a second boy, whose business it was to trim and shape the rough hole into an "eye." To do this he had to lay it on a piece of lead and drive a sharp tool clean through it. This he left in; then laying the needle on a steel rest, with the little punch still sticking through the hole, he gave this a tap with his hammer on both sides, which cleared the hole and made it take the shape of the punch employed. This sounds like a

very slow process, yet we are told that some of these little fellows had become so dexterous through constant practice that they could trim the eyes of 400 needles in an hour, dealing blows on the punches with such unfailing accuracy that they would sometimes astonish lookers-on by piercing holes in hairs and threading them through one another, so as to form an almost invisible chain—an evident proof of their skill.

In these busy days, when needles in abundance are a necessity, a very large proportion of those used in Great Britain and in many other parts of the world (for English needles are now celebrated) are manufactured not only in Birmingham, but at Hathersage, Studley, and Alcester, and more especially at Redditch, a pretty rural town in Worcestershire, in the neighbourhood of which a great deal of the emery necessary for the grinding and scouring of these useful articles is found.

Any one who has ever used a needle can easily believe that its value and fine quality depend on that of the steel wire of which it is formed. Needle-makers do not make or "draw" this wire themselves, but buy it wholesale at Sheffield or Birmingham. The best thing for us to do will be to follow a quantity of it from the railway wharf to the store-room of one of these large establishments, and note what is done with it there.

The first consideration seems to be preservation of each great coil or bundle of shining wire from rust. It is well covered up, and then hung round the dingy room (a nice warm one, by the way) on wooden bars or racks. As the wire is of different degrees of thickness, according to the varying sizes of the needles to be made out of it, it is tested by means of a steel gauge, the edge of which is perforated with small numbered slits of different sizes, into which a sample of the wire is fitted. Each coil weighs about fourteen pounds, and is, I am told, twenty-four inches in diameter; if it were less it would be more troublesome to straighten the short pieces into which it will presently be cut. The length of the wire in each bundle varies according to the thickness of it, and there is, as you know, a great range from No. 1 to No. 12, which are the sizes of ordinary sewing-needles. We can count only twenty-two thicknesses of wire to the inch in No. 1, while in No. 12 there are two hundred. If we were to uncoil and straighten out this No. 12 it would stretch over a mile and a quarter. Imagine a line of nearly 50,000 needles, and imagine too what a different style of needle these wires will in turn form. Some almost as thin as a hair will be made into dainty things fit to stitch a fairy's wardrobe with; others will be stout and strong enough to pierce through coarse canvas sails, thick carpets, or rough coarse sacking. Some bearing behind them an almost invisible train of the finest cambric cotton or soft yielding silk; others leading along packthread, twine, or thread as strong as string. There are also exceptional needles, such as surgeons use for sewing up wounds and for other purposes. They are not at all like ordinary ones; each is made singly, ground, and polished by hand.

But now to business, for some of the great coils are being carried off to the "cutting-shop," where they are to be snapped into many thousand lengths of two needles each; and as these little pieces have so lately formed part of a circle of wire—and curved needles would certainly be useless—they must next be straightened. It is a curious process, and one worth watching; so come along, and open your eyes wide.

The worker who is going to cut them grasps two big handfuls of wire, and after

determining, by means of a little measure, the length they are to be cut—that of two needles in one—he holds them between the open blades of a large sharp pair of shears or scissors, which are fixed against the wall, and snips them sharply off by pressing one of the handles of the shears, which he moves with his leg by means of a string-sort of contrivance he slips it into.

And next for the curious operation of "straightening" out the slight curve, which at one time was done by hand and mallet—a tedious enough process it must have been. Now the worker half fills two strong iron rings, some six or seven inches in diameter, with the short lengths of wire, and using a curved bar of iron with a handle at each end and two openings along its centre, he places the rings with the needles in them on a flat iron plate with a fire under it. The slits in the iron bar pass over the rings, and are only stayed by the projecting ends of the wires, enabling him by holding fast the handles to move the rings, and their contents, while pressing heavily as he rolls them up and down. The action of one slim wire on another tends to straighten and equalise the whole mass, and by the time he turns them out of the rings the little curved bits will be all as straight as new needles should be, though they will not otherwise as yet particularly remind you of any such useful things; for they have neither eye nor point, being blunt and clumsy at each end, and dulled by exposure to the fire—altogether most unpromising morsels of metal.

NEEDLE "RUBBING," OR STRAIGHTENING.

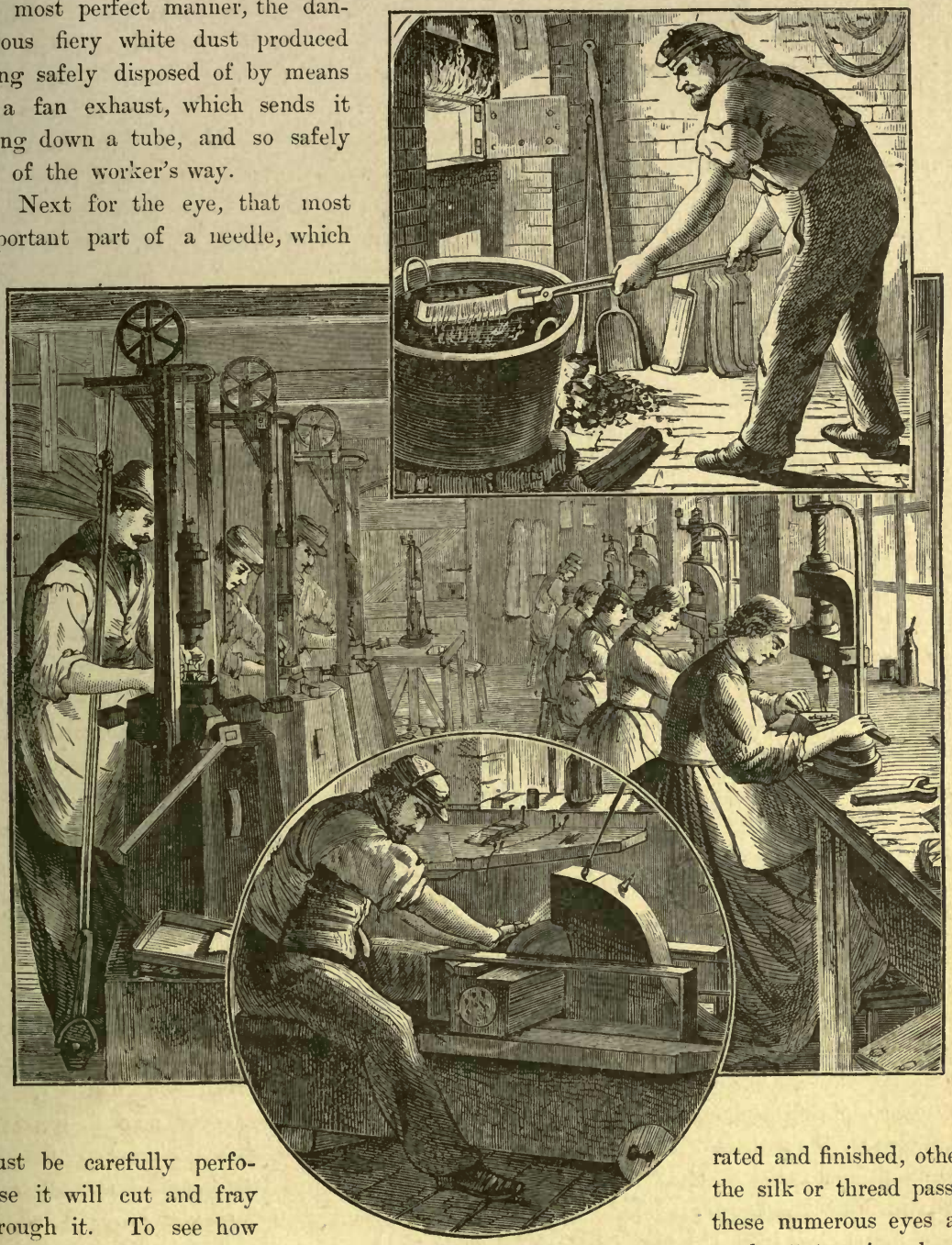
The next operation is that of "pointing." Until lately this has been a very dangerous and distressing task, always done by a "dry grinder," who, seated in front of a large revolving gritstone, took up a handful of the wires to be pointed and held their ends to the stone, pressing them firmly to it with his other hand, turning them about the while until they began to get sharp, and finally, amid a shower of flying sparks, showed the long tapering points he was aiming to produce. But this treacherous stream of fine steel and stone dust, getting down his throat and settling on the poor worker's lungs, did much mischief, and invariably caused him a painful malady too well known as grinder's asthma.

Many humane and skilful men tried at various times to introduce improvements on this dangerous method of sharpening steel; but, strangely enough, the "grinders" themselves stoutly opposed all and any innovations that, by decreasing the danger of their task, might also decrease the wages they received for it. Actually, when expensive new machinery for the purpose was first brought to Redditch in 1844, the enraged "pointers" rose in a body and destroyed it, declaring that they would be ruined by such aid!

But truly it is said "time works wonders," and now we see the needles surely and expeditiously pointed at the rate of 40,000 an hour by means of a simple enough machine invented in Germany, the use of which, once tolerated, saved many a life. The pointing-machine consists of a revolving metal wheel, on which the pointless wires drop from an inclined tray, to be held fast by a vulcanised india-rubber band which encircles it. As the wheel turns, the ends of the wires meet a hollow grindstone placed at right

angles to the wheel, which, as they touch it, rolls them round and points the wires in the most perfect manner, the dangerous fiery white dust produced being safely disposed of by means of a fan exhaust, which sends it flying down a tube, and so safely out of the worker's way.

Next for the eye, that most important part of a needle, which must be carefully perforated and finished, otherwise it will cut and fray the silk or thread passed through it. To see how these numerous eyes are made, we must pass through to the "stamping-shop," where a stamping-machine, which is also, I believe, a German invention, is busy. It is a solid block of stone, with a mass of iron on its upper surface. On the upper side of this is placed the under half of a die; above it is hung



TEMPERING, STAMPING, AND POINTING.

a heavy hammer which weighs forty or fifty pounds, and on the face of which is fixed the other and upper half of the same die. This sturdy hammer, or "ram," is regulated by a lever directed by the worker's foot, and can be brought down with a heavy "thud" straight on to the sounding iron bed, or lower die, into which the man steadily drops the steel wires one by one, bringing down the hammer at the same moment. Up it goes again, and the wires slip into an iron pan, each one having now a channel or "gutter," as it is called, with a slight depression to show where the eye will be. So rapidly is this "guttering" done, that one worker alone has prepared in one hour almost 8,000 needles for the piercer, whose turn it is to take them. These "piercers," mostly boys, work at small hand-presses. They must have good eyes and nimble, skilful fingers for the work before them, which consists in taking pieces of wire and spreading them out upon an iron slab, keeping all the ends of these numberless sharp points collected in the hand. The middle is then brought through the press, and being stopped for a moment, down come the hardened steel pins, that dash two little bits or "eyes" one against the other in the centre of each wire; but these eyes are far from complete, and have to be "spitted," an operation which is also performed by boys, who run their "spits" through each hole, and so collect a double solid comb or steel fringe of about a hundred needles, which will then be handed over to be "filed"—that is, to have removed all the surplus metal and little roughnesses left by the stamping. Next these fringes of needles are slipped under a clamp, fashioned so as to hold them firmly down at the edges; the ridges are firmly and rapidly filed by well-skilled workers, who then take the spitted wires, and bending them in the middle, snap them into two halves. One row held together by the spit is placed in a kind of pliers, and a sweep of the file removes all roughness and marks of its late attachment. Then the spits are withdrawn, and for the first time we realise that ordinary needles are really in progress of manufacture.

But as yet they would bend or break very easily, and so must be hardened—that is, spread out in great numbers on plates of sheet-iron, and placed in a "muffle" or furnace with arched doors and fitted with bars, on which the wires can rest and bake until they are of a white heat or straw-colour. They are then withdrawn and put into a cistern fitted with a perforated vessel which is filled with water or oil, and left there till they are cold; they are then washed in alkaline liquor and dried. They still need to be tempered, which is done by putting them on an iron plate with a fire under it for a short time; on this they are gently shaken. As this "tempering" sometimes slightly bends them, especially if hardened in water, they are handed over to a worker to be hammered straight. To make them look bright and sharp they must be "scoured;" to watch which curious process we must go downstairs to the scouring-room, where are a number of men engaged in arranging large numbers of needles in parallel bundles on pieces of rough canvas. Among, or rather beside, the bundles they place a mess of soft-soap, oil, emery, and fine sand, and then roll them up into long parcels, which are corded tightly and carefully round. These parcels are then put under heavy slabs weighted with iron, or what we might have taken for large and overgrown mangles driven by steam-power; by this means hundreds of thousands of needles are rolled about one over the other for several days, being taken out at intervals to be washed in soap-suds and re-packed with the soft-soap mixture. At

last they are put into a thing like a sieve, and so dexterously shaken that somehow most of the needles arrange themselves side by side, so as to be easily picked out and placed in neat little heaps ready for the "bright-room," where the "header," a tidy girl, next takes them in hand to turn all the heads one way. A puzzling business it looks to sort that great tangled mass of steel, but in a twinkling the young woman seems to have obtained a certain amount of order, and while we are watching the rapid movement of her deft fingers, which, by-the-bye, need thick washleather gloves, the whole tangled mass has fallen into rank and file—their heads one way, the points the other. Then comes "picking for crooks," that is, picking out all the crooked and defective needles. This a woman sitting at a queer-shaped little table does, by rolling over and over single layers of needles, surely and swiftly detecting all those that are in the least imperfect. Of course these are many, but her quick eye and hands soon see and sort out. At the least defect she puts them from the chosen lot. Then they are "handed," that is, those that are either too long or too short are turned out, and the whole mass is especially cleared of broken-eyed or broken-pointed members. It is curious to see how these girls, with their sharp, well-trained eyes, can spy out offenders at a glance, even when hidden away in a bundle containing some thousands, deftly catching them up with a needle, and throwing them aside as unworthy their bright companionship. In some works, I believe, even this is now done by machinery.

At last we are bound for the grinding and finishing-room, in which are found two lines of wheels, all revolving rapidly by means of steam. The engine-room is just below. Here the grinders, holding a handful of needles each, apply them to one of the small stones, revolving so swiftly that our dazzled eyes cannot follow its turns. Having soon smoothed off any little inequality in eye or point, he then hands his work over to the "polisher," and it has only now to pass through a final touch-up on a polishing-bob, with putty powder sprinkled on small rotating wooden wheels, covered with soft, comfortable chamois leather, before it is at length pronounced ready for packing in those little, slate-coloured paper cases so familiar to all industrious ladies.

Even the making of these papers, which are soon flung aside with little concern, employs a great many people; and we are shown some curious machines which cut and fold so expertly that we can scarcely wonder when we are told that by their aid, and by constant practice, many of these women can count out and neatly paper somewhere about 3,000 needles in one hour. We cannot help thinking how, at that rate, surely needles enough would be papered in a day to serve all the world's sempstresses for a year; yet we are told that from the Redditch British Needle Mills alone about two hundred millions of the very best kind of needles are annually sent on their travels, not to mention a great number of more ordinary and extraordinary kinds, from the huge packing and sail needle to the sort used for the tiniest gloves. When we remember that there are also large manufactories in France and Germany, as well as other parts of England, we give over trying to guess at the amount of sewing of one kind or another that must be constantly going on all over the civilised world. How did the Greek and Roman women ever get their work done?

Before leaving this place let us peep into one of those many shabby little bags from which we have seen the needle-scourer so constantly helping himself. We find that they all contain supplies of shining blue-brown emery of various degrees of fineness. This

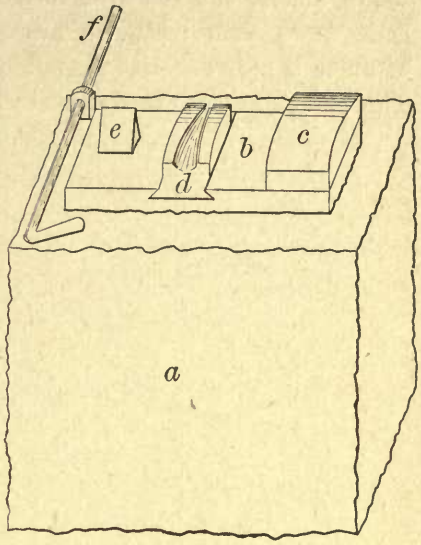
substance is one much employed not only by these needle-makers, but also by cutlers, smiths, engineers, locksmiths, jewellers, and all workers in metal, by lapidaries in the cutting and finishing of precious stones, by opticians in the preparation of the finer kinds of lenses, by glass-grinders, marble-polishers, and many other workers; in fact, all sorts of busy folks seem to find uses for it. Even our own industrious aunts and mothers and sisters have a neat little "emery-bag" hidden away somewhere in their workboxes, whilst Betty the housemaid declares that there is nothing so useful as this same powder when she wants to get out any rust-spots, or put an extra polish on to the steel stove and fire-irons. The men of the family also frequently patronise it in the shape of hones and razor-strops, sold under many names, but equally composed of emery, ground-glass, and paper pulp.

What, then, is this useful substance, we ask, and whence do we get it? Common as it is, no one here seems rightly to know anything concerning it more than, as one of the needle-scourers, a Yorkshireman, hesitatingly observes, "It war stoof as coom fram the iron-warks nigh." But we get further information on the subject, and find that this infusible powder is a mineral consisting mostly of alumina combined with a small proportion of iron, that it is not affected or acted upon by acids, and that it is found in masses lying imbedded in certain rocks situated in various parts of the world, especially in Turkey, Persia, and Sweden, only a small proportion being obtained from the English iron-mines.

Before anything else can be done with them, the big uneven lumps have to be broken into small pieces, and these are ground to a rough powder, either in large iron mortars or in steel mills. This powder, which requires careful washing, is then sifted through sieves having networks of different-sized wires. According to the closeness of these, the powder is numbered, which is a great convenience to the worker, who knows at once the fineness and kind he requires, whether in its dry state or in the form of emery cloth or paper—things easily made, the powder being sifted on either material while newly coated with glue. These cloths are often used wrapped round bits of wood, and form a kind of file, or long flat slabs are dipped into strong glue and then into emery. As to the emery-cake, it appears to be composed merely of the powder and plenty of beeswax mixed into a kind of paste that is well worked about in water, and made into little lumps of brownish dough, which is very useful, I am told, in the dressing of the buff-edged wheels we so constantly find revolving in every busy corner of our Wonderland.

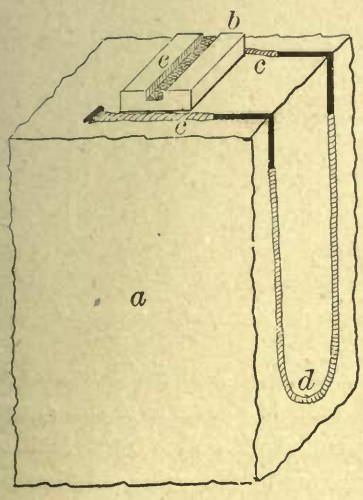
There is one kind of tool that we find in some form or other in almost every workshop, whether it be of the wood or the iron worker, and this is the file. It is made in many shapes and degrees of coarseness and fineness, from the coarse rasps that the horseshoer and woodworker uses, to the fine dead smooth watchmaker's file, whose teeth are so fine that you can hardly see them. A truly wonderful tool is this file; and yet it is simply a piece of steel with teeth cut in it in single rows, which are called single-cut, and double rows, one crossing the other, which are called double-cut files. The steel must be of the finest quality of tool steel, and the names of the various shapes are: flat, square, round, half-round, three-cornered, warding, or thin files, and so on; but these general shapes are sub-

divided into many others, as rat-tailed (which means a well-tempered round or square file), parallel files, in which the width and thickness are equal from end to end. Here you see a file-cutter's shop; the workmen sitting at their low benches cutting files with their oddly shaped hammers and short, stubby chisels.



THE FILE-CUTTER'S ANVIL.

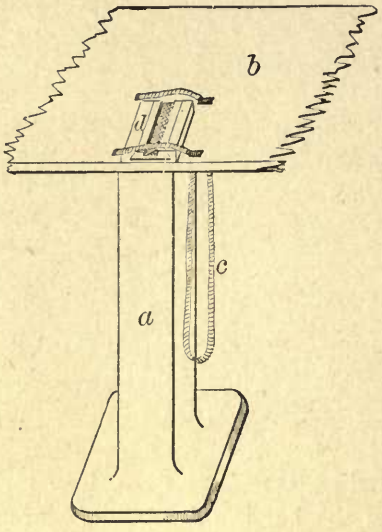
The file-cutter's anvil, *b*, rests upon a stone block, *a*. At F is the gauge to determine the length to cut off the blank, by means of the chisel, *e*. At *c* is the forging block, and at *d* is a block for shaping half-round files. This block, as you see, is let into the anvil so that it may be removed and replaced by one suitable for other shapes of files. After the files are forged, their surfaces are ground smooth upon a grindstone that is about five or six feet in diameter when it is new, and runs about two hundred revolutions in a minute. But as the stone wears smaller, it is made to run faster. They must not be made to run too fast, however, or they will be liable to burst into fragments and commit great destruction. At the railway works at Ashford, in Kent, two workmen were standing one on each side of a large grinding-stone, when the stone burst into many pieces. The grinder's "*horse*," as he terms the bench he sits on, was held by a chain as thick as your finger, but the chain was snapped like a pipe-stem, and the *horse* thrown back, knocking part of the wall down; part of the stone went through the roof, and one piece, weighing six or eight hundred pounds, was found several months afterwards in a water-tank that was about sixty feet higher than the grinding building. Fortunately, nobody was hurt, but both the men were covered with mud out of the grindstone trough, and one of them, after scraping the mud from his eyes and face, looked first at the roof of the building and then at the general destruction around him, and remarked in great astonishment, "*Why! there must a bin a 'splosion or somethin'!*" which made his fellow-workman laugh heartily, in spite of the narrow escape he had just had.



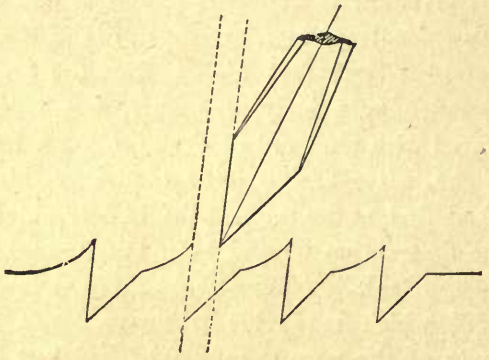
FILE-CUTTER'S BLOCK FOR LARGE FILES.

From the grinder the files go to the cutter, whose block, as you see, is composed, for large files, of a base, *a*, of stone about 18 inches square, and supports an iron block, *b*, which has a recess to receive the file to be cut. But between the file and the bottom of the recess a lead block is put, so that the teeth on the bottom side of the file will not be damaged when cutting the teeth on the top side. For small files, a block or an iron stand is used, because the blows are light. In either case, the file is held on the block by a leather strap, *c c*, having a loop at *d* into

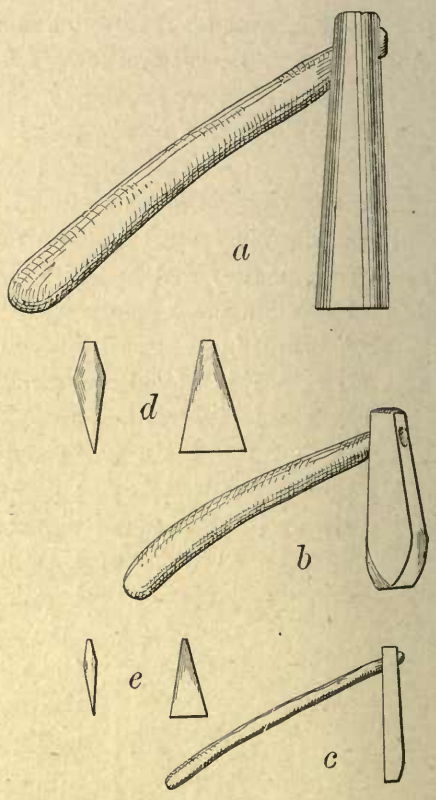
which the cutter places his foot. The file-cutter's hammers are the queerest and most primitive-looking ones to be found in any trade, looking more like the crude hammers found among the relics of those old and uncivilized nations of whom we now know but little more than what we can glean from their burial-mounds. But the file-cutter's hammer is very effective in striking a dull heavy blow without much if any rebound to it. The hammer at *a* is used for rasps and coarse files, and weighs from seven to eight pounds.



BLOCK FOR SMALL FILES.



THE FILE-CUTTING CHISEL SHOWN ENLARGED.



THE FILE CUTTER'S HAMMERS AND CHISELS.

That at *b*, for ordinary work, weighs about five pounds. For small files the hammer at *b* is used, weighing but a few ounces. The form of chisel used is shown at *d* and *e*, and it is held, as you see, at an angle, so that one face stands parallel with the front face of the tooth, whose shape at the cutting end is just as it is shown in the enlarged view.

He places the file in the block with its tang or handle end towards him, sets the chisel upon it with the cutting edge at an angle or diagonal across the file, and with a blow produces a cut throwing up a tiny ridge or tooth; then forward goes the chisel and down goes the hammer, producing another tooth, the blows falling so quickly that both hands

are kept in motion. By going along the file in this way once only he produces a single-cut, but most files are *double-cut*, which is that a second course of chisel cuts are carried along the file, the chisel slanting to the opposite direction across the file, so that the second course divides up the first one into numerous teeth. The second course requires lighter blows than the first one, but must be just as evenly cut.

If you examine a smooth file you will be astonished that they are so regularly spaced, when the cutter has nothing to guide him in adjusting the chisel. Let us watch a cutter as he begins again after he has been away to sharpen the chisel. First, you see, he rests the chisel on the face of the file, and moves it along until it touches the last cut,

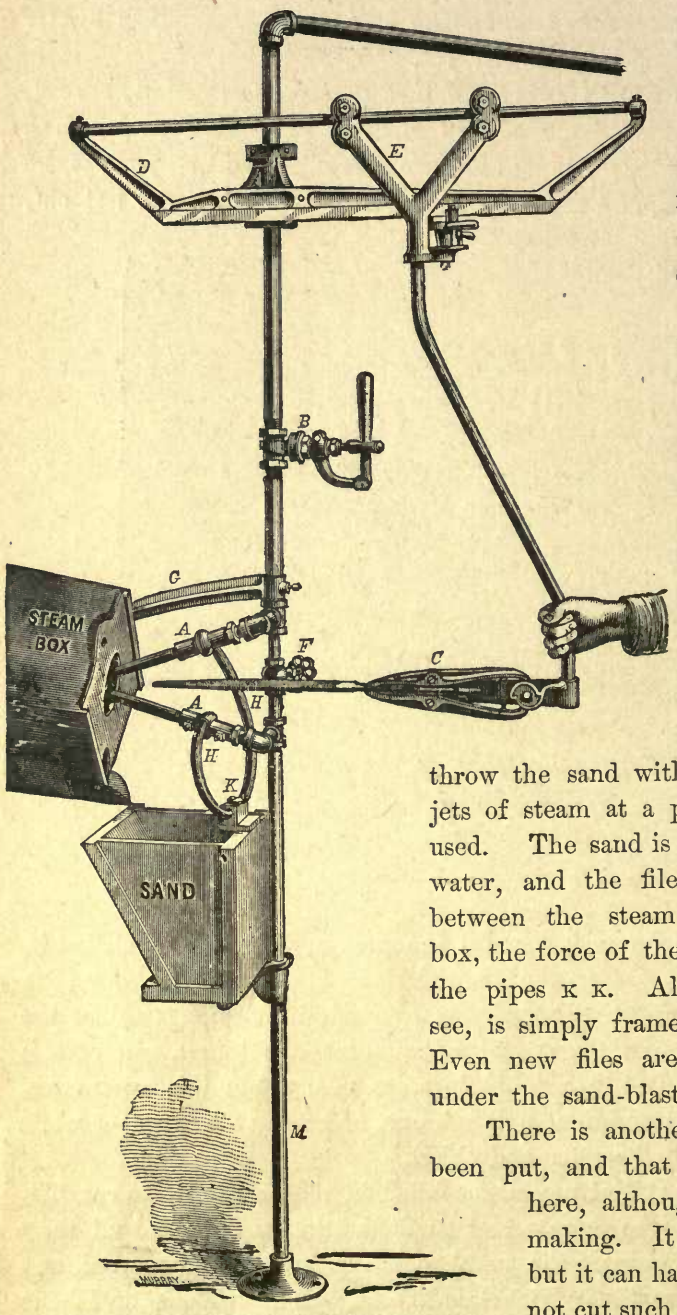
FILE-CUTTING.

which is his starting-point, and then moves it forward the proper distance and strikes it, cutting a recess across the file. After getting the first cut right, along he goes, blow after blow falling without any hesitation or further trial. A great deal of what is called the skill of workmen lies in the exercise of thought and common-sense, but in a case of this kind it is nothing but experience, and so thoroughly do some men attain this experience, that they will cut a fine, smooth file and then a rough one, and read a newspaper while both hands are actively at work with hammer and chisel.

For a great many years the most skilful mechanics failed in their attempts to cut files by machinery, for there appeared to be some secret in file-cutting that baffled all their efforts. Within the last few years, however, the problem has been completely solved, and there are large manufactories, such as the "Nicholson Works," at Providence, in Rhode Island, where dozens of busy machines are at work cutting files of all kinds and shapes, so that a very large proportion of the files used in America are machine-cut.

After the cutting comes the hardening, for which the teeth are first coated with a

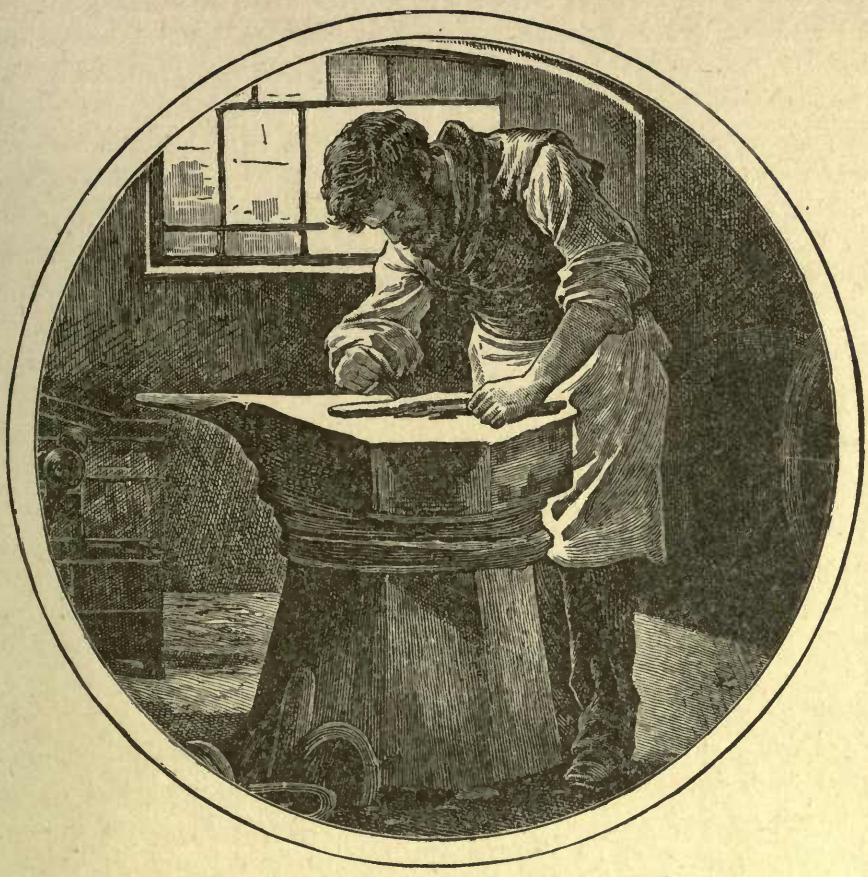
paste composed of salt, charcoal, and burnt leather or flour paste, and then heated in a bath of melted lead, and when red-hot plunged into water which contains as much salt as it will hold without the salt settling. A dip for a few minutes in a weak bath of oxalic acid removes the burnt paste from the teeth, a brush cleans them, and a night in a bath of thick lime-water prevents them from rusting. They are then dried quickly by heat and are ready for sorting and packing.



FILE-SHARPENING WITH THE SAND-BLAST.

If we stand at the door of the file-cutter, however, we shall sometimes see a package of files come back to be recut, because the teeth have worn dull. In this case, the old teeth are simply ground out and new ones are cut in. But of late years a new and curious method of sharpening old files has been found. It consists of projecting a stream of very fine sand against the backs of the file teeth, and thus grinding them to a sharp edge again. To throw the sand with sufficient force against the teeth, jets of steam at a pressure of about sixty pounds are used. The sand is put in the box, which also contains water, and the file, held in the claws C, is passed between the steam nozzles A A, and into the steam box, the force of the stream lifting the sand up through the pipes K K. All the remainder of the parts, you see, is simply framework to support the file-holder C. Even new files are made sharper by putting them under the sand-blast.

There is another use to which the sand-blast has been put, and that you may just as well be told of here, although it has nothing to do with file-making. It has been called engraving on glass; but it can hardly be called engraving, as it does not cut such very clear lines. A pattern is put over the glass article to be sand-blasted, and the sand projecting through the holes in this pattern cuts away the surface of the glass, leaving it with a dull, frosty appearance that is very pleasing to the eye.



"BY HAMMER AND HAND ALL ARTS DO STAND."
The Blacksmith's Motto.

OUR KNIVES AND FORKS AND SPOONS.

THE inquiry has very often been made, "What becomes of all the pins?" That, of course, is altogether unanswerable. But *can* anybody tell me what does become of the penknives?

Think of all the schoolboys in our England alone who are continually getting a new knife, either by an outlay of their own pocket-money, or more often still from good-natured friends and relations, who find it a most ready and acceptable gift, as no matter how lately a lad was seen with one it is sure to be broken, or, more likely, to have vanished "somewhere," that great limbo of schoolboy property where everything was last seen. A penknife is a trifle scarcely worth making a fuss about, you may think, yet a good ordinary three-bladed knife goes through over a

hundred processes in the making; and I am told of one house in Sheffield, the great centre of the cutlery trade, that every week turns out no less than 1,500 dozens of these nowise to be despised articles, of which they show some 12,000 different patterns to choose from.

The earliest specimen of cutlery known was the "whittle"—ancient Chaucer describes one of his pilgrims owning it, "A Sheffield thwytel bare he in his hose"—a rude, rough article enough compared with what we call a spring-knife; its blade was made of bar steel, placed in a clumsy wooden or horn handle. And yet Gilbert, Earl of Shrewsbury, thought so well of them that he sent Lord Burghley a case of "Hallamshire whittels, beinge suche fruictes as his pore country afforded with fame throughout the realme." After a long time this was succeeded by the "jack-knife," a great improvement upon the whittle, inasmuch as its sturdy blade could, though with some difficulty, be doubled down into a groove in the stout handle, but there was no spring to make it an easy task.

To watch the making of a spring or pocket knife we must first peep into one of a number of small dingy-looking rooms, in which we shall find either one or two men at work roughing out dozens of blades, which, if for spring-knives, are made of cast-steel only. On one side of the apartment a bright clear fire is burning. Near it is a large trough full of coke, specially prepared. Another trough full of cold water stands by a small anvil, which, together with hammers, some dies, and a number of bars of the best cast-steel, form all the contents of this primitive-looking workshop.

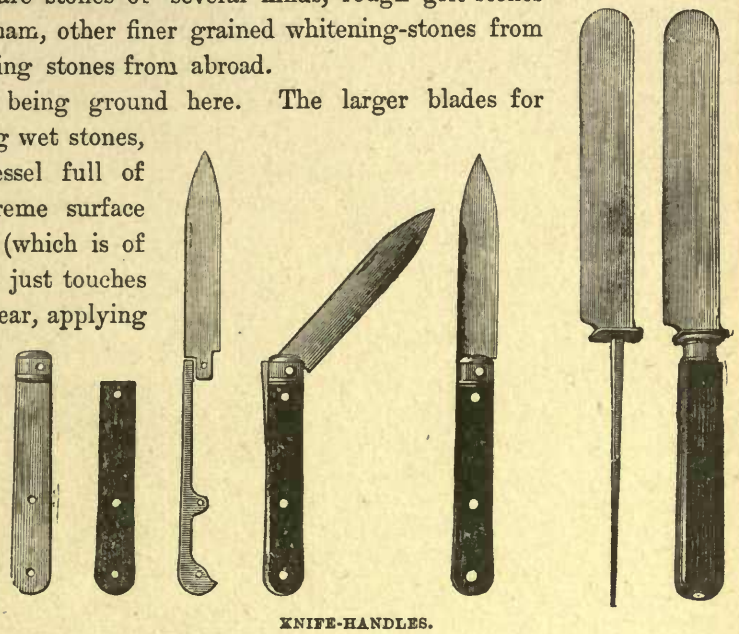
A man known as "the forger" is busily employed working the bellows with one hand, while with the other he frequently takes out a red-white bar of steel, the end of which reaches to the centre of the fire. This he carefully examines, for the heating of the bar requires great skill, care, and experience, as if it gets at all overheated it will become altogether useless for any kind of cutlery, and if not heated enough it will not have acquired the softness necessary for shaping into the thin sharp blades required to cut with. But when the forger judges the metal to have arrived at a proper degree of heat, he places the end of it on his anvil, and quickly "strikes" it into a blade, using a hammer the size of which depends upon the work he has to fashion: for small penknife-blades its striking surface should not extend over more than an inch. When the blade is thus roughly struck into shape, it is cut off the metal bar, which is again heated, to go through the same process, and the blade is placed with others ready for the "grinder," whose business it is to "scorch" or rough-grind the tangs, that is, the top parts where the blades join into the handles, and also to give them a slight "chorl," or nick, that they may not crack when they presently go through a hardening operation that awaits them.

From the grinder's "hull," with its whirling stones and all its noisy clatter of machinery, we follow our blades down into the marking-room, where we find them being heated to a dull sullen colour, or what the worker calls "worm-red;" then they are one by one placed under a heavy steel punch, which, driven down on them by a blow of the hammer, leaves the name of the maker cleanly cut out on each blade. While still "worm-red" the little snick, or thumb-mark, by means of which we open a spring-knife, is rapidly chiselled on one side, and these bundles of marked blades are again returned to the forger who first had them in hand, as they have to be hardened and tempered—two most important processes, upon which their character as sharp and useful pocket-knives will depend.

The hardening is done by heating the blades until they are at a particularly bright point of redness, then plunging them suddenly straight down into a bath of chilled water; but as this operation renders them not only very hard, but also very breakable, they have to be subjected to another treatment. The blades, having been cooled, are rubbed in fine sand, to clean them thoroughly, then laid on a flat steel tray and put into a kind of oven to bake, until they show quite a deep blue tint, the worker watching closely, and at a certain point of the colouring removing some of them, as the degree of blueness or tempering differs according to the uses the knives are intended to serve.

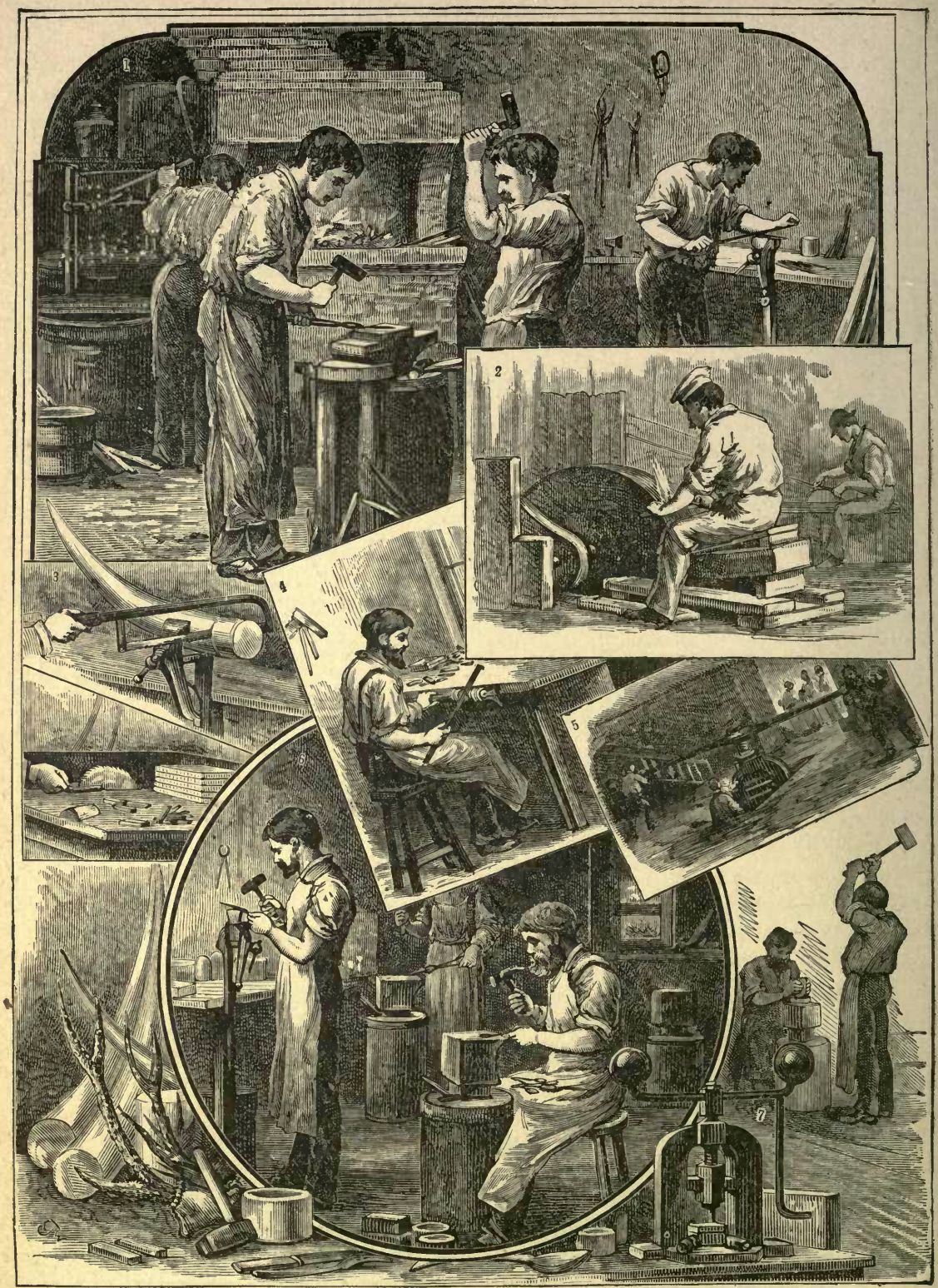
Again the blades pass to the grinder's "hull," where each at last is to have a proper edge bestowed on it. Here are stones of several kinds, rough grit-stones from Wickersley, near Rotherham, other finer grained whitening-stones from near Sheffield, and fine finishing stones from abroad.

Knives of all kinds are being ground here. The larger blades for table-knives are ground on big wet stones, which hang over a great vessel full of water, so that the very extreme surface of the revolving stone wheel (which is of course moved by steam-power) just touches the water. The grinder sits near, applying each blade to the wheel by means of a flat stick. They are improved by being still further ground, or "glazed." The tang being fixed to a movable handle, our blade is applied to a wooden wheel, the edge of which is coated with emery-cake—that composition of emery, tallow, and wax we spoke of. After this they are polished and finished off with emery-flour on wheels thickly banded with soft buff leather. But I am watching the blades for table-knives, and not noticing that our boys' useful friends do not progress at quite so rapid a rate.



KNIFE-HANDLES.

When the bundles of "spring-blades" have been hardened and tempered, and had something of an edge put on them, they are handed over to the fitters, each blade being supplemented with the rivets, "bolsters," "pins," and other portions necessary for fitting up a complete knife; and as every different knife requires a different kind of set, they are all carefully numbered. Let us watch the putting together of one of these neat and useful pocket treasures. Here is a fitter just setting to work at a neat four-bladed pocket-knife. The principal parts seem to consist of the steel spring, or back of the knife, varying according to the number of blades, and the outer and inner scales. The spring, having been well tempered, is filed down to the thickness of the blade, and slightly bent, to help the motion of the blade. It is then rubbed on a surface of glue and emery, and the interior is further polished on a steel burnisher, that there may be no unevenness or "catch" as the knife



KNIFE, FORK, AND SPOON MAKERS AT WORK.

1. Forging, Filing, and Tempering Table-blades. 2. Grinding and Polishing Blades. 3. Cutting Ivory.
4. Boring the Handle for Shaft of Blade. 5. Stamping Spoons. 6. Forging Spoons and Forks.
7. Press for Cutting Out the Spaces between the Prongs of Silver Forks.

closes. The fitting of the blades into the springs is a work that can only be well done by experienced hands. The worker we are watching tries them all several times, filing and fitting most patiently before he seems at all satisfied with the "set" of each blade, which, it appears, must stop of itself at exactly a right angle with the handle when half open, and must, in closing, fall quite clear of any part of the little partition which keeps it from the neighbours, of which it sometimes has several of different shapes and sizes.

The handle is composed of an inner and outer scale, the inner ones, made of brass or German metal, forming those little openings into which the blades fit so nicely; the outer one is the neat cover of creamy ivory, which, I should think, makes its contents more likely to please some dainty lady than any one else. Now follows a drilling of holes, and the fitting of pins or rivets that are to hold the various parts together. A small, silvery-looking plate is fitted into an opening drilled into one side of the ivory surface, and the handle, or "scales," being fastened together, the blades are fitted, as we have noted, with the greatest precision. When the knife is so far completed, the blades and springs are returned to the grinder for another polish; and the whole is finally fitted and pinned together, the corners rounded and filed, and smoothed, first on a sand-buff, then on a gloss-buff, where emery and oil polishes them to any extent; last of all they are sharpened on Welsh hones. Some of these "pocket-knives," of which Sheffield furnishes any number of dozens of grosses, are perfect marvels of ingenuity, and show how carefully the "fitter" must work. Here a two-bladed wonder, so small that it can hang among the "charms" on a chain, lies side by side with another horn-handled brother containing, besides the ordinary blades, a corkscrew, a turnscrew, a railway-carriage key, a bottle-opener, a button-hook, a file, a saw, and other useful things, all safely closing up in their several compartments.

We are satisfied by now that the making even of a pocket-knife is worth noting. Its construction employs, as we have seen, forgers, grinders, buffers, spring-makers, scale and pin makers, fitters, and steel-workers, even after the poor Swedish worker, deep in the Danemora or other mines, has provided the metal. Very likely the African or Indian elephant or rhinoceros hunter has furnished the materials for its handle, at peril of his life and limb.

It is well worthy noticing what a variety there is in the materials used for making the outer scale or surface of pocket-knives, from stained wood to blackest ebony, from brass to elaborately-chased silver and gold, from commonest bone to creamiest ivory and shining mother-o'-pearl. Of horns there seem to be any number sliced up for this purpose—elk, antelope, buffalo, walrus, rhinoceros, and especially the rough antlers of the handsome Bavarian stag, which are particularly suited for the purpose. Then, too, there are numerous cheap composition handles, pressed to resemble horn or tortoiseshell, and smart, fancy German articles, which might well be warranted to look shabby in a very short time. Some of the commonest pocket-knives—at least their scales and blades—are now made by machinery, but I would scarcely recommend them, unless it is to the most inveterate young losers, for that is almost all they are good for as far as my own personal experience goes.

Having said and seen this much concerning knives, let us note something about forks, those now indispensable articles, the use of which was of old so little known in England, that in a quaint book published in 1611 the travelled author writes:—

"I observed a custom in all those Italian cities and towns through which I passed

that is not used in any other country that I saw in my travels. Neither doth I think that any other nations of Christendom doth use it but only Italy. The Italians and also most strangers that are there corrmorant in Italy do always at their meals use a little fork when they cut up their meat. This forme of feeding, I understand, is generally used in all places in Italy, their forkes being for the most part made of yron or steele, and some of silver; but those are used only by gentlemen. The reason of this their curiosity is, because the Italian cannot by any means indure to have his dish touched with fingers, seeing all men's fingers are not alike cleane. Hereupon I myself thought good to imitate the Italian fashion by this *forked* cutting of meate, not only while I was in Italy, but also in Germany, and oftentimes in England since I came home; being once *quipped* for that frequent using of my forke by a certaine learned gentleman, a familiar friend of mine, who in his merry humour doubted not at table to call me *Furcifer*, only for using a forke at feeding, but for no other cause."

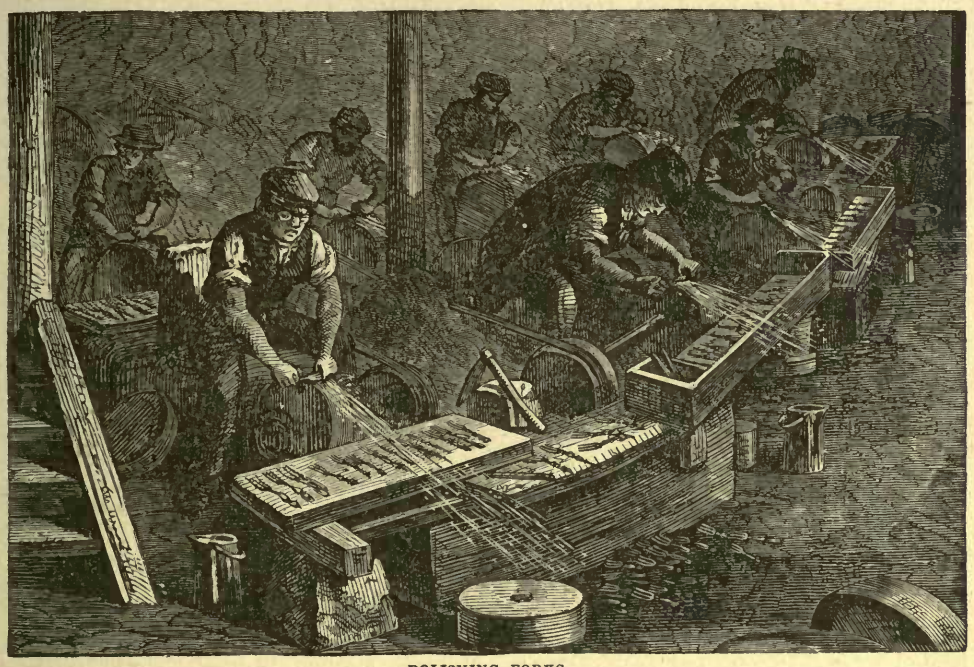
This term "furcifer," let me add, meant a slave, punished by being forced to carry a fork of wood upon his neck; and very evidently the use of forks was at first much ridiculed in England, as an effeminate piece of affectation. In one of Beaumont and Fletcher's plays, "your fork-carving traveller" is spoken of with much contempt. Ben Jonson writes:—

> "*Sledge. Forks!* What be they?
> "*Meercraft.* The laudable use of forks,
> Brought into custom here as they are in Italy,
> To the sparing o' napkins."

At one period the loaves were made round; they were cut in slices which were piled by the side of the carver, or *Ecuyer Tranchant* (cutting squire). He had a pointed carving-knife, and a skewer of bone, silver, or gold, which he stuck into the joint. Having cut off a slice, he took it on the point of the knife, and placed it on a slice of bread, which was served to the guest. This ancient custom of serving meat on the point of the carver was until of late general throughout the continent of Europe. A leg or haunch of mutton had always a piece of paper wrapped round the shank, which the carver took hold of with the left hand when he carved the joint, and such is still the custom in Lower Germany and Italy. We, who imitate very often without knowing why, have imported the custom; and pointed knives are still general on the Continent, it being so difficult to leave off old customs, even after the necessity that occasioned them has ceased. Yet the fashion came but slowly into England, where for a long time knives and spoons alone were provided for company, and only very particular folk thought a fork at all necessary, as they were considered merely articles of luxury, used by the great ones of the land for eating fruits and preserves. Such dainty-mannered guests usually brought their especial forks with them, as a host could scarcely be expected to keep a supply of such really fanciful unnecessaries. I am told that these earliest specimens of iron, steel, or silver, sometimes headed with gold and silver handles elaborately chased, were in shape more like split spoons than anything else, and at the best had only two long, blunt prongs—in that resembling the form of some of their humbler modern kind we may still meet with in out-of-the-way country places in company with peculiarly

substantial knife-blades, which, broadened out, no doubt to fit the mouths of the diners, were evidently intended to be used shovel-fashion.

But while we are thinking of these old-fashioned and clumsy two-pronged forks, here is a grimy "forger" heating the bar of steel with which he proposes to make one of the neat modern three-pronged kind we are now so familiar with. At one end of this bar he, by means of his anvil and hammer, forms the tang, or end that is to go into the handle—this is sometimes so long that it comes right through; then the shoulder, or stop piece, and the shank, or middle of the fork, at one end of which he leaves a piece of steel. This he hammers out until it is of the length and width of the prong end



POLISHING FORKS.

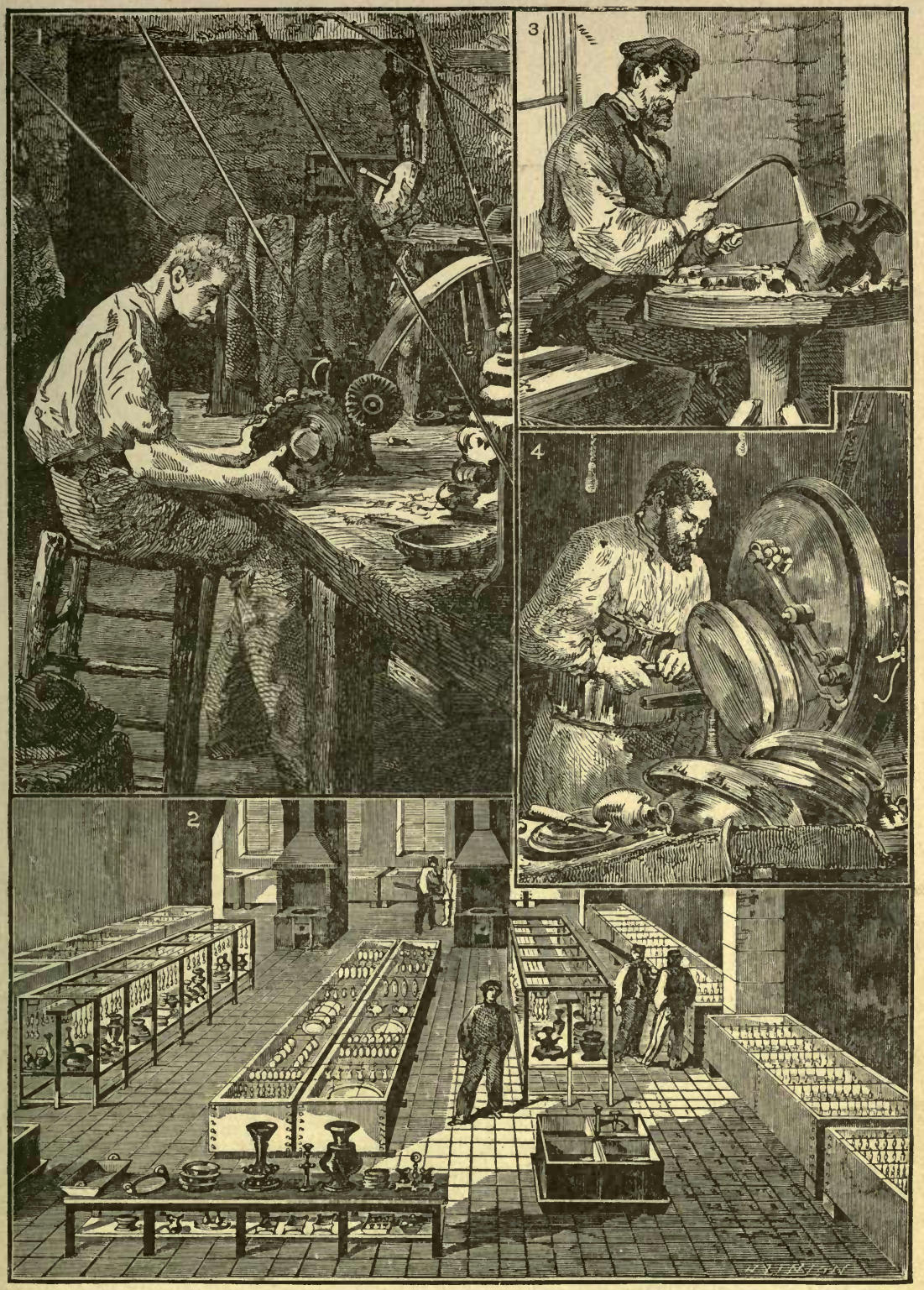
of a fork. Another worker then takes it, and having made it very hot, lays that end in the lower half of a steel die, the upper part of which is allowed to come down on it with a sudden heavy thud, which cuts out the pieces and leaves three prongs roughly formed and ready for the grinder, to whose noisy "mill" it is now carried, then to the shop to be hafted, or fitted with a handle, then back again to be finally ground, and "buffed," and polished. The forks are then tied up in neat packets ready for the cutler's shelves.

Though steel forks yet hold their own in the kitchen and for general purposes, they have of late years been superseded in the dining-room by elegantly-shaped electro-plated rivals, which, although composed of a cheap metal, present the general appearance of silver. Two hundred years ago plating was mentioned as giving "the use of silver forks, which is by some of our gallants taken up of late, without offering the same temptation to the light-fingered gentry." They take the place of the plating mentioned by Horace Walpole, who, writing in 1760, says:—"I passed through Sheffield, which is one of the foulest towns in

England, in the most charming situation. There are two-and-twenty thousand inhabitants making knives and scissors. They remit £11,000 a week to London; one man there has discovered the art of plating copper with silver." And a very valuable discovery surely. But to understand the "how and why" of the dainty modern forks, fish and fruit knives, now so generally used, not forgetting the cruets, coffee and tea pots, salvers, and cups, we must travel back to busy Birmingham, and learn something of the process of electro-plating. We are fortunately just in time, for in the large factory we happen to visit they are melting and mixing three metals into one, of which forks, spoons, fish and dessert knives, and other useful things are to be cast; and we are shown the great melting-pots full of a grey broth composed of copper, zinc, and nickel, which, combined in different proportions, form the various alloys known under a variety of fine names, but which, when plated, we generally sum up as "electro" or German silver. At the right boiling-point the "pot" containing it is lifted out of the furnace, and after much stirring and skimming, the metal is cast into ingots, or "strips," weighing about eighteen pounds each. This is called the "strip casting," and very hot, tiresome task it is, judging from the appearance of the several workers. The grey strips are next heated in annealing furnaces, and allowed to cool before being passed through iron rollers worked by steam, then again annealed, which processes harden and improve the metal.

MODELLING, CHASING, AND ENGRAVING.

The great plates of German silver, having been thus cast and annealed and rolled to a given thickness, are next cut into pieces and "punched" into "blanks," or flat outlines of the forks or spoons required. This is done by means of fly-presses, the cutters of which come down with a heavy pressure upon the metal, which rests on a die screwed to the press. These odd-looking, flattened-out forks and spoons are again annealed, and their handles stamped with the "fiddle" or other pattern they are intended to bear; any little roughness or defect is then filed off, and they are taken to the "bowler's shop," where there are several workers "bowling" the flat spoons, or bending and rounding the prongs of the forks. A great snapping and banging seem to be constantly going on here, for the stamping-machine is not a particularly quiet one. It has a kind of heavy hammer, or drop, on the lower surface of which is a steel die, and this snaps straight down on another strong die which is screwed fast on an anvil resting on a large stone. The hammer, which has



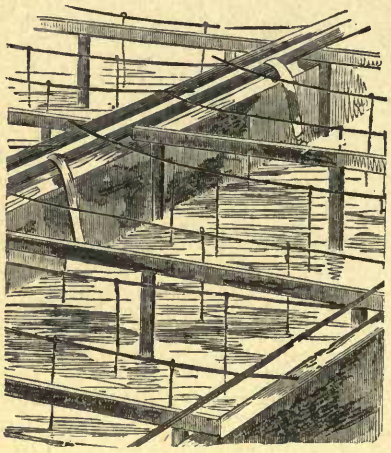
AT THE ELECTRO-PLATERS'.

1. Polishing.
2. Batteries and Troughs.
3. Soldering with the Blowpipe.
4. Turning Oval Dishes.

grooved sides, slides easily up and down between two upright posts, or "poppets," by means of a rope passing over a pulley. The rope and hammer are attended to by one young worker; another rapidly passes the blank spoons and forks under the hammer, and between the two dies which stamp them into form. Of course, when the "bowl" or bend varies, as it often does, according to the size or shape of the blank, these dies have to be changed.

But now for the magic electro-plating bath, which is to transform all these plain metal objects into silver—or, at least, something very like it. This curious apparatus consists of two distinct parts, namely, the voltaic battery, from which the electric current is obtained, and the vat in which the silvering or gilding—for either can be done—takes place.

The battery consists of one or more large cells (earthenware jars), according to the quantity of electricity to be generated and the intensity of the current required. These oblong plating vats, or depositing troughs, contain cyanide of potassium diluted in many gallons of water; across each vat two brass rods are laid lengthways, one on each side; on these are copper-wire hooks, to which the forks, spoons, or other articles to be plated are hung, after having been boiled in potass to cleanse them from all dirt, rust, and impurities, and also washed in nitrate of mercury; thin plates of silver are also hung at regular intervals in the vats, so that they face the articles to be plated on both sides. A connection is formed with the galvanic battery, and the silver, released in minute particles from the plates, rapidly attaches itself to the surface of the metal objects, the thickness of the deposit depending upon the time the articles are allowed to remain in the bath; an ounce and a half of silver to the square foot of metal is considered very good plating, though, of course, more may be deposited.

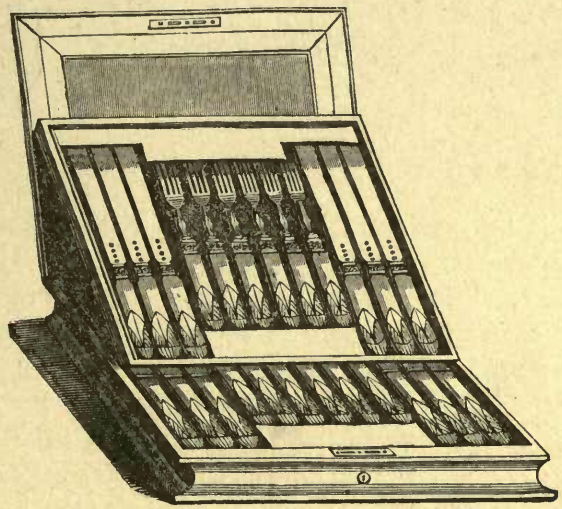


THE VATS.

When the process of electro-plating is concluded, which will be in from three to six hours, according to the quality of the plating required, the articles are taken from the depositing vat, boiled in clean water, and dried in sawdust. They look shabby and dull enough as yet, but I am informed that they will brighten up after they have been passed under brushes wetted with stale beer, and undergone a thorough rubbing with Calais sand. These brushes are not composed of bristles, but of fine brass wires, that, flying round in a lathe, do most effectual work, and prepare the things for the women who wait to burnish each one of them with a variety of blunt tools that can poke about in all the holes and corners. The whole surface is greased over with soap to avoid scratches, and well burnished with blood-stone, our forks and spoons and other especially shining objects getting extra care, and being finally touched up with a dab of rouge to make them more silvery-looking before they are packed in layers of soft tissue-paper or washleather ready for the shops, or placed side by side in pretty velvet-lined cases—the making of which supplies home-work to very many industrious men and women—and in them the pretty plated things look very tempting.

So much, then, for the knives and forks and spoons, and for the great changes that have taken place in cutlery since the days when observant Chaucer sang of the "Sheffield

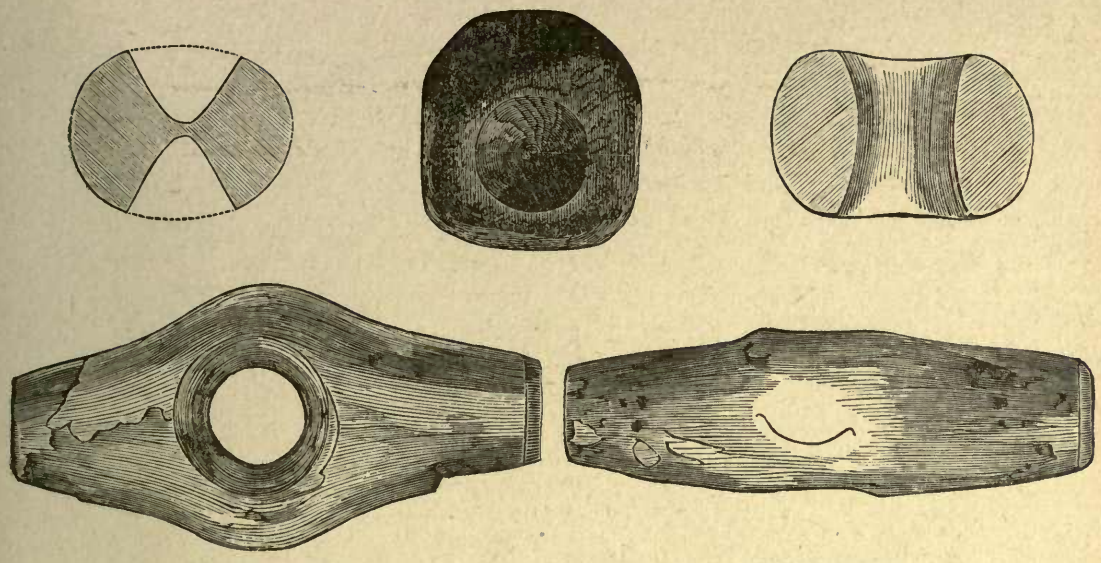
thwytel," and even since the later times of those "Hallamshire whittels" mentioned just now. Hallamshire, as perhaps you know, is the old name for Sheffield and its neighbourhood, whose busy inhabitants evidently already excelled in this particular industry, which probably owed its rise to the great natural advantages found in an abundant supply of iron, wood, coal, and water-power, all ready to the worker's hand. Then, too, when the religious disturbances in the Netherlands drove away its skilled men, those who worked in metal at home naturally settled down in the iron-working districts, where their descendants are to be found to this day. No doubt their steadiness, taste, and energy gave a fresh impetus to the native cutlers, though it was some time yet before the idea of a "spring" pocket-knife suggested itself, and then only as a clumsy, stiff contrivance. Surely they would have considered the knife lately exhibited by one of the great Sheffield firms, and containing no less than 1876 blades, all different, yet perfect, as something magical and not to be meddled with by Christian fingers.



THE VILLAGE SMITHY.

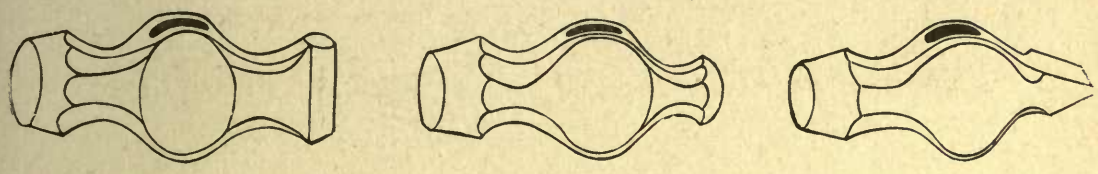
MAN'S TOOLS AND THEIR USES.

AMONG all the tools that man uses there is none of more interest than the simple hand hammer. It is the most ancient as well as the most universal tool in use, and is found in a greater variety of forms than any other. Indeed, it is found to be at the foundation of all the mechanic arts. It would appear that nothing could be simpler or easier to use than the hand hammer, but you must know that some of the work done by it requires wonderful skilfulness, and that we can find none in our whole Wonderland that requires more. The earliest and crudest form in which we find the hammer is the stone maul, which was a water-worn piece of stone smallest in the middle, so that the hand could grasp it—this being the hammer of prehistoric races, who had not learned to give it a handle. Later on we find these mauls rudely dressed to shape so that the hand could hold them more easily and firmly. At a still later period, handles were provided by tying them to the stone heads with withes; and, finally, as man's wants and mechanical knowledge increased, the stone maul was given an eye and a handle, and rudely, as you see, shaped to somewhat resemble some of the stonebreaker's hammers of the present day. But it is with the hammers of the present day that we are more particularly interested. Some of them will be quite familiar to you, but others you will find novel, curious, and interesting. Only the principal forms of hammers used in some of the common trades are shown, for to give all the forms of hammers that are now in use in the different trades would fill dozens of pages.

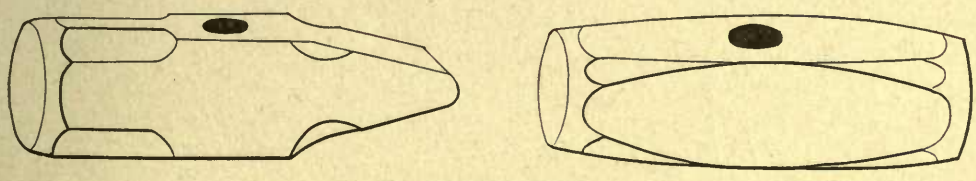


END ELEVATION. SIDE ELEVATION.

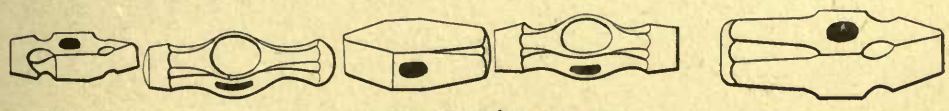
ANCIENT HAMMERS.



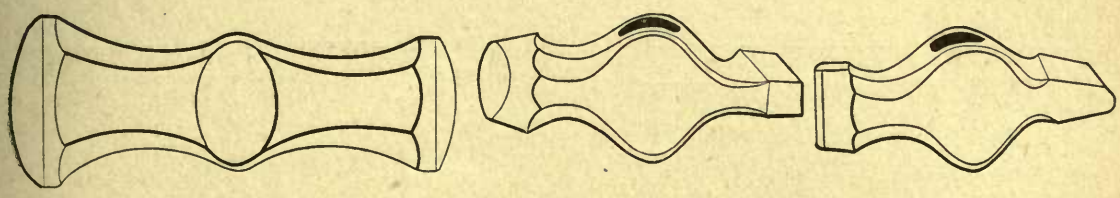
MACHINIST'S HAMMERS.



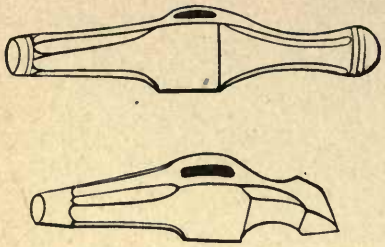
THE SLEDGE-HAMMER.



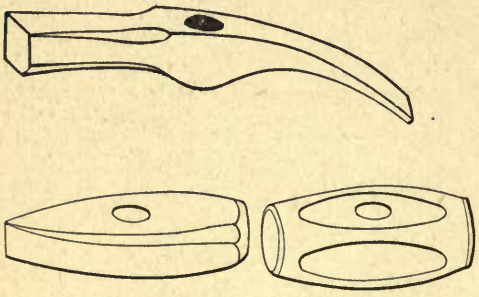
THE BLACKSMITH'S HAMMERS.



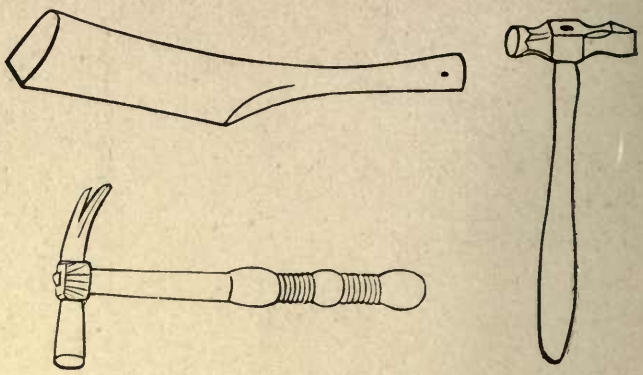
THE COPPERSMITH'S HAMMERS.



THE BOILER-MAKER'S HAMMERS.

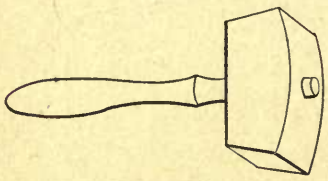


THE STONEMASON'S HAMMERS.



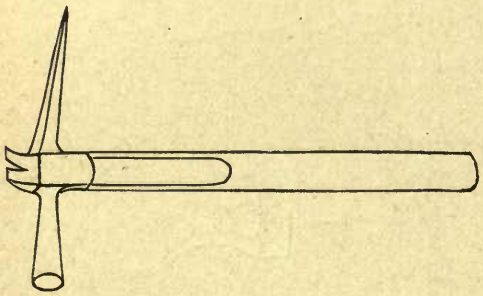
THE PLUMBER'S HAMMERS.

THE COOPER'S HAMMER.

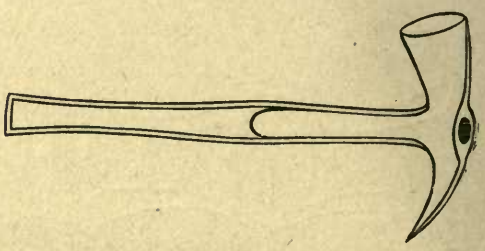


THE MALLET.

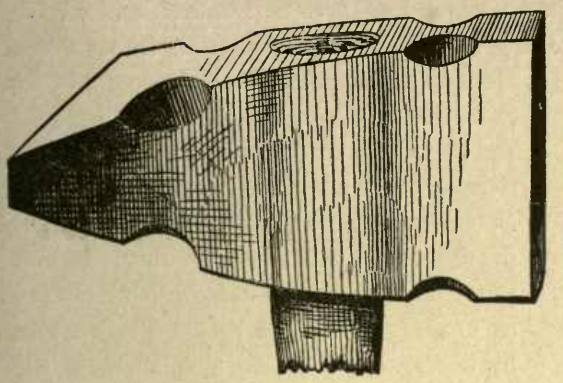
THE COACH-TRIMMER'S HAMMER.

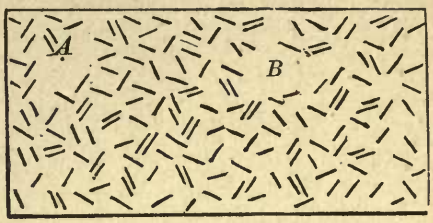


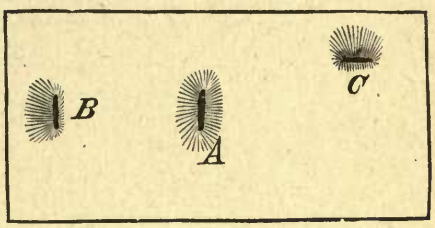
THE SLATER'S HAMMER.

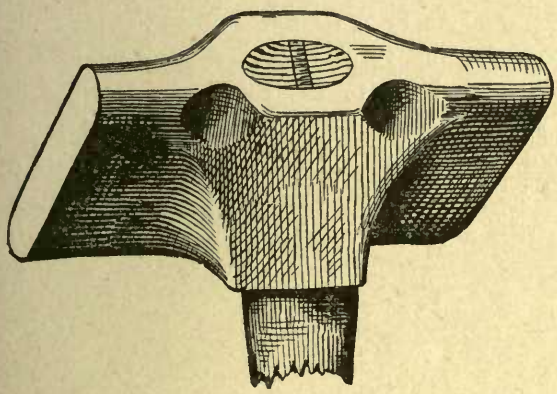


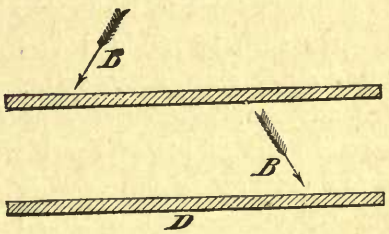
THE FIREMAN'S TOMAHAWK-HAMMER.











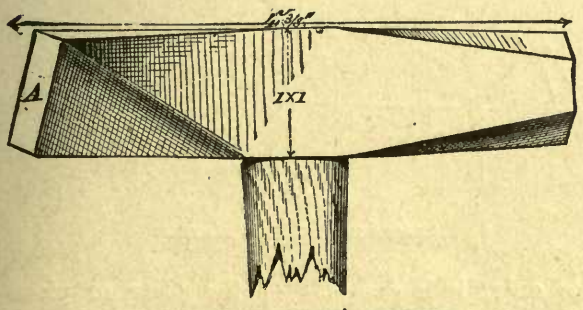
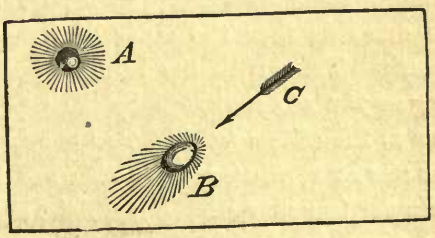
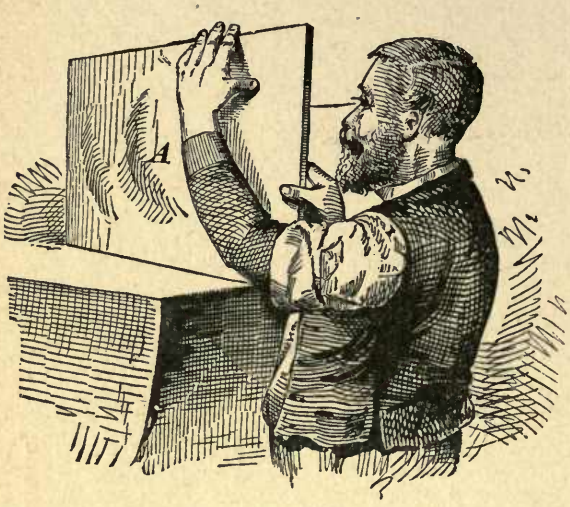


PLATE-STRAIGHTENER'S HAMMERS.



THE EFFECTS OF A HAMMER-BLOW.

But every one of these hammers, you must know, has its own peculiarities, and for every single or slight alteration of form there is a good substantial reason that it has taken time, thought, and experience to find out. Sometimes it is in the nature or kind of the blow it is to strike, sometimes in the situation of the work it is to do, and sometimes it is to save unnecessary work, as in the case of the odd-looking hammer the plate-straightener uses, which is shaped as you see it so that by bending his arm in different positions, and turning the hammer over and over, he can stand in one place and strike blows which will fall lengthwise, at any angle or on any part of the plate's face, as is shown by the dashes, which are meant to represent blows.



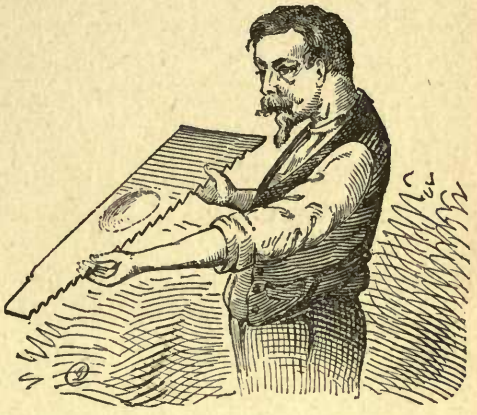
STRAIGHTENING THICK PLATES.

As to the differences in the methods of using these hammers, it would take a large book to explain them, but a few words about it may not be out of place. First, then, you must know that the most powerful effects may be produced by the small hammers weighing not more than half a pound, and with light blows, because on cold metal there are two quite distinct actions produced by hammer blows. The first is to strike a blow that will penetrate all through the metal and bend it, while the second is to give such light blows that their effects do not sink deep and merely stretch the surface of the metal. In either case, the effects of the blow depend to a great extent upon the direction in which the hammer travels to deliver it. If the hammer falls straight down, as at A, the metal is affected equally all around the spot that receives the blow. But if the hammer moves sideways while falling, the effects are produced more on one side than the other of the spot struck. Thus, with the hammer travelling as you see indicated by the top arrow B, the effects would be as shown by the star at B, whatever the shape of the hammer face may be. When light blows are given to stretch the metal on one face only, it is one side of the plate or piece of metal being stretched more than the other that alters its straightness.

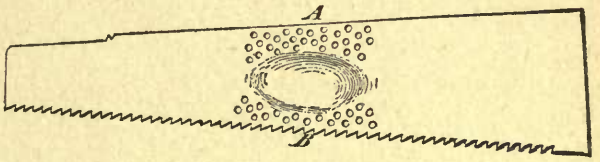
STRAIGHTENING THIN PLATES.

The machinist uses his hammer to drive and also to stretch the work, employing for the stretching action the middle hammer, which he calls the "ball pene." The sledge is used for driving purposes in a great many trades. The blacksmith, as you know, uses his hammers to stretch metal while it is hot, while the coppersmith's hammers are used to drive as well as to stretch the metal and form it into shape.

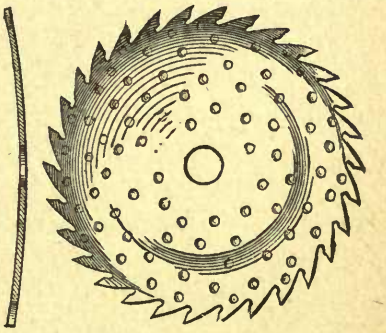
There is far more skill required to use the hammer for stretching than for driving purposes, but I must tell you that a great part of the skilfulness lies in knowing just where to strike the blow, for a blow struck in the wrong place makes the work worse instead of better.



In straightening thick iron plates, such as the safe manufacturers use to make into bank safes, the straightener holds up the plate on the anvil before him and sights the sides of the plate; the shadows he finds on it telling him what parts of the plate are high or low; some of these shadows being shown at A. But it requires a great deal of experience to even be able to detect these shadows on the rough plates the safemaker uses, and a good deal more to decipher their meaning.



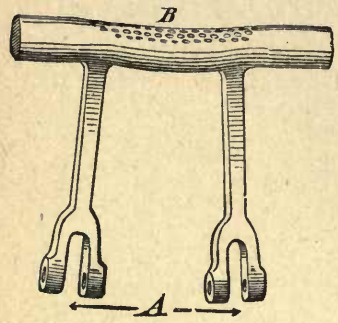
The straightener on thin plates rests one end of the plate on an anvil, while he lifts the other end and presses the plate down a few times, so as to be able to find out where it moves the most, which he calls a "loose place." He straightens the plate by stretching the metal all round about this loose place, first on one side and then on the other, turning the plate around and around, and over and over, while the blows fall thick and fast without a moment's hesitation. To straighten a woodworker's hand-saw is considered a good example of difficult work. The straightener holds the saw in both hands and bends it up and down, finding, perhaps, the dish-shaped "loose place" you see. In this case he hammers the saw with a round-faced hammer at A and at B, to stretch the blade and take out the loose place. But, suppose it was a circular saw, and that it was bent as you see, then he would hammer it well around the outside to stretch it, but would not let any blows fall around the eye, and this would cause the saw to open out flat instead of being dished.



STRAIGHTENING SAWS.

To give you an idea of the wonderful effects of light stretching blows, suppose we had a shaft several inches thick, and that it was bent as you see, the two arms being too

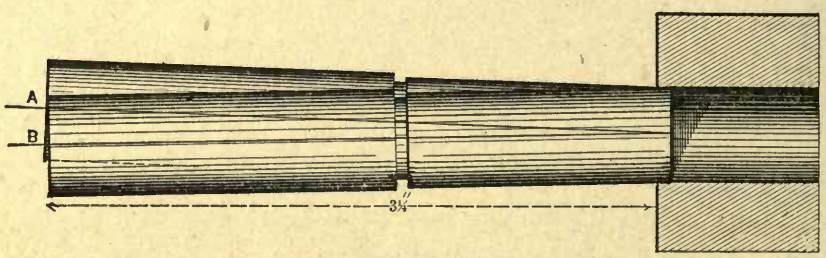
wide apart, then we may take a hammer weighing a quarter of pound and hammer away at B, which would straighten the shaft and close the arms together at the same time. As this stretching process is always done with the "pene," or smallest face of the hammer, it is called "pening."



STRAIGHTENING A SHAFT.

You are all familiar with the carpenter's boxwood measuring-rule, or his "two-foot rule," as he calls it; and a very useful tool it is, filling all his needs for common plain work. In olden times it was considered that it was also sufficiently accurate for the machinist and the instrument-maker, but we have found that it is of but little use for those purposes, as you will soon see. It is divided into inches, and these inches into eighths, sixteenths, and thirty-second parts of an inch; and so for any measurement less than the one thirty-second part of an inch, you have to guess what the exact measurement is. Now, in making fine machine-work, it is found that the fit of the pieces will not be a good one unless the sizes are correct to the one five-thousandth part of an inch. Of course you will think that even the one thousandth part of an inch is a very small affair, and could hardly be noticed, but if you had a pocket-knife that was one one-thousandth part of an inch loose in the blade, you would say that it had a very bad "headache," as boys call it.

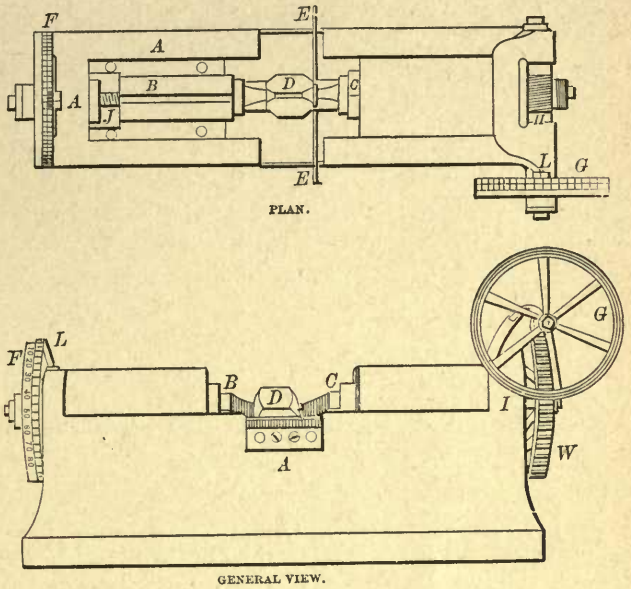
To convince you of this, here is an experiment that was made, the picture being the full size. A piece of iron was bored with a hole one half an inch in diameter, and an iron plug was made that was one one-thousandth part of an inch smaller; and when the plug was put into the hole, it would shake backward and forward from A to B, and from B to A. This was done to make a workman see what a very bad fit—an error in size or thickness—a piece would be if it was a thousandth too small.



ONE-THOUSANDTH OF AN INCH.

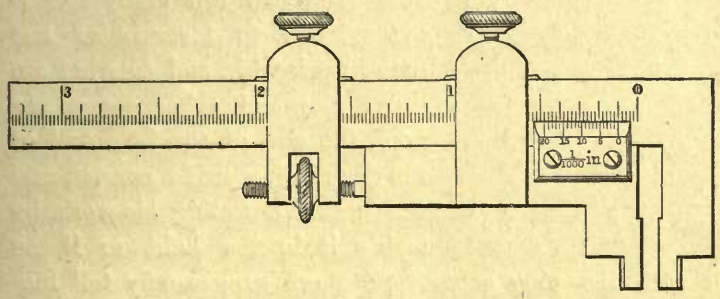
Now the closeness with which work must fit depends upon the kind of work, and you must know that you could tell the difference between the fit of the plugs that fitted to the same hole, even if one was only the five thousandth part of an inch larger than the other, providing that the hole and the plugs were quite round and straight, and were made of iron. And so it comes about that engineers make machines that will measure as fine and close as they possibly can. Sir Joseph Whitworth has made a machine that will detect an error of the one millionth part of an inch. It is called the "Millionth Measuring Machine," and the way it is used is this:

A piece of work, D, is placed between two feelers, B C, that may be moved up to it by wheels and screws, and between C and the end of the work is placed a flat piece of iron E, and when this piece is held just so that it will move easily with the finger and not fall down, the machine is set to the standard measuring-piece D. This being done, the workman notes in just what position the wheel G stands in—this being the wheel that he moves to make C touch the gravity-piece E. He then takes out the standard-piece D, and puts in the piece of work he wants to make, of exactly the same length as D, and moves the wheel G to the same place as before, and if the gravity-piece E falls down, the piece of work is too short; while if piece E is so tight that it will not move with the slightest touch, the work is longer than the test-piece D. It is found that a difference in length of the one millionth part of an inch may easily be detected in this way, and that is why the machine gets its name of the "millionth measuring-machine."



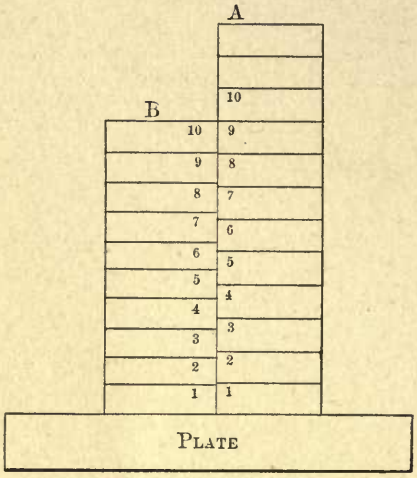
THE MILLIONTH MEASURING-MACHINE.

It is a very common thing for workmen to measure their work to a thousandth part of an inch, which is done with several kinds of tools. First, there is the Vernier calliper, so called from Monsieur Vernier, the Frenchman, who invented it, and as this is a very important and ingenious tool, we may as well try to make you understand the principle it works on. It has, as you see, a bar, with a jaw on one end of it, and on this bar is a second or sliding jaw, which may be fixed on the bar by the "set-screws" you see, which secure the two straps to the bar. The sliding jaw has a small screw on it, and on this screw is a "nut," so that revolving the nut moves the sliding jaw, and all that is necessary is some means of finding out when this jaw has been moved the one thousandth part of an inch, which is done in this way: Suppose we take a strip of steel A, and divide it equally by lines as marked from 1 to 10, resting its end on a plate P, and then take another piece and space it off

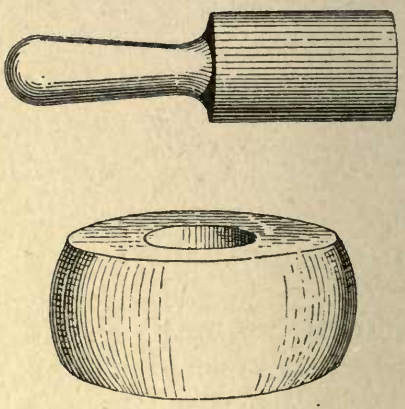


VERNIEE CALLIPER.

equally by lines as from 1 to 10, but making the 10 divisions on B exactly equal in length to the 9 of those on A. Then if we took one of the divisions on B and cut it up into 10 parts and put one of the parts on line 1 of B, another on line 2 of B, another on line 3 of B and so on, we should make the 10 divisions on B equal to 10 on A; and so it is plain that if the divisions on A are 10 to an inch, then the two lines marked 1 will be the one

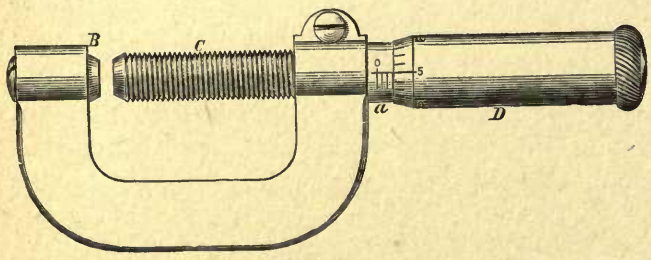


THE PRINCIPLE OF THE VERNIER.



STANDARD GAUGES.

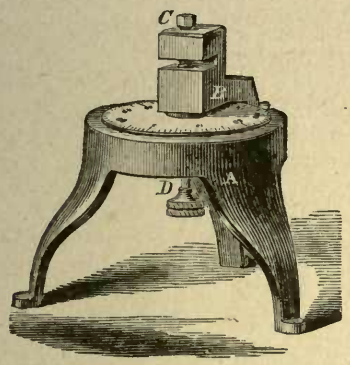
hundredth part of an inch apart; those marked 2 will be two one-hundredths of an inch apart; those marked 3 will be three one-hundredths of an inch apart, and so on. Again, if A had divisions that were spaced 50 to an inch, and B had 20 divisions that just equalled in their total length 19 of the divisions on A, then lines 1 would be the one thousandth of an inch apart, lines 2 two one-thousandths of an inch apart, and so on. Now the sliding jaw on the Vernier corresponds to our piece of steel B, and the bar corresponds to A, so you see it is an easy matter to measure the one thousandth of an inch. This tool, you can easily see, is not suitable to measure or test round work with, and so what are called plug and collar gauges are used, the size of the hole and of the plug being made correct, and the workman testing his work by trying it in the hole, or if he wants to test a hole, he tries it with the plug gauge. So these gauges only tell him whether the work is the right size or not, and do not tell him how much it is wrong.



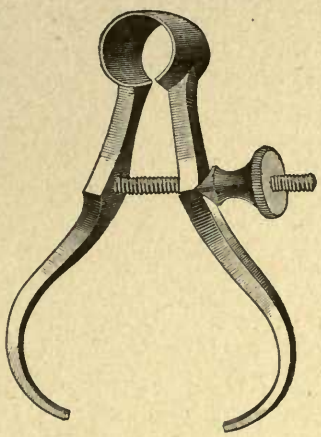
MICROMETER CALLIPER.

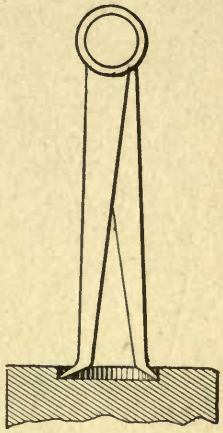
Here we have a delicate and handy instrument called the "Micrometer Calliper," that will not only measure to less than the thousandth part of an inch, but will also tell us the exact amount of error in the work, and its principle is quite simple. A piece of steel shaped like the letter U has at one end a stop or plug, B, for the work to rest against, while

through its other end passes a screw C. The work goes between B and the end of the screw C. At D is a tubular piece or "sleeve" as the machinist calls it, fitting over the stem of the screw, and the tapered end of this sleeve is divided off in equal line divisions—say twenty-five in number. Now, since one whole turn of the screw causes it to move end-

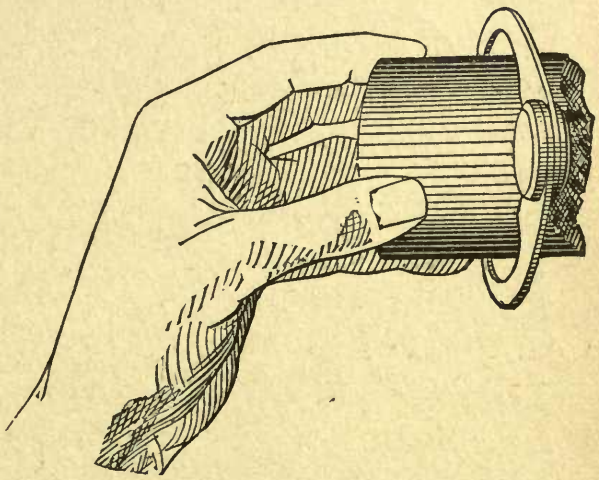


SHEET METAL MEASURING-MACHINE.

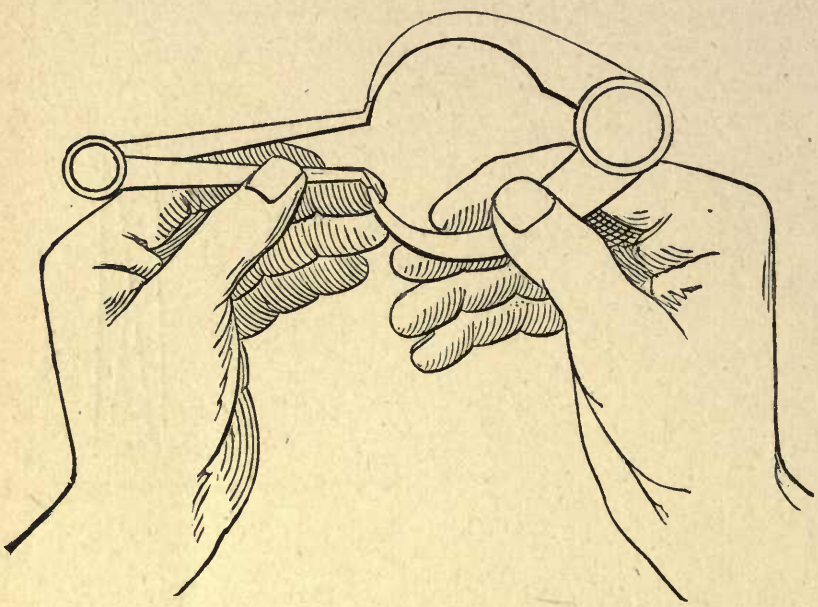

OUTSIDE CALLIPERS.


INSIDE CALLIPERS.

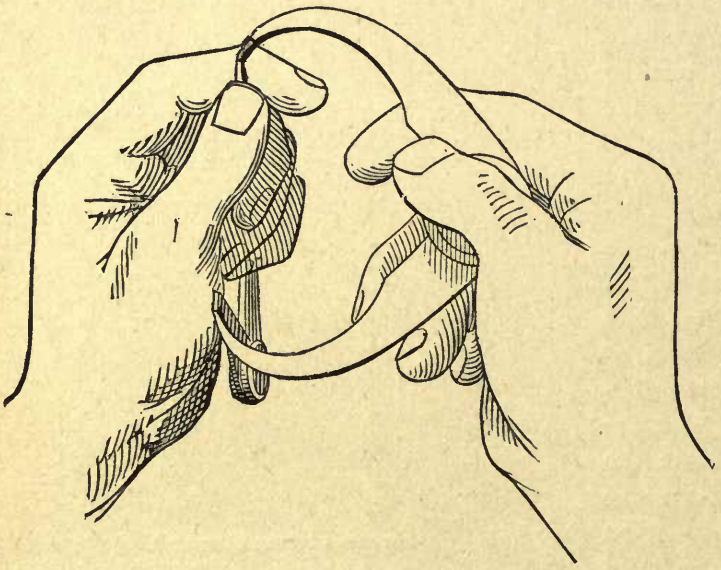
ways the one fortieth part of an inch, therefore moving it by the sleeve D one twenty-fifth part of a revolution will quite clearly move the screw endways the twenty-fifth part of a fortieth, which is the one thousandth part of an inch, and the line of division that you see standing horizontal on the end of D will come exactly opposite to the horizontal line marked off on the screw stem. But if we were to move the screw until it touched the work and gripped it between the end of the screw C and the foot or plug B, and the horizontal line marked O came half way between the lines on the end or bevelled edge of D, the measurement would be to the one half of one thousandth. The vertical lines you see at A are simply divisions of an inch, the same as on a measuring-rule. And I may tell you that for fine measuring these rules are made of steel, and marked off as fine as one hundred lines in an inch, and yet you can see them quite distinctly and also the spaces between them. For measuring sheet metals a different kind of measuring instrument is used, a plate being employed instead of the sleeve D; but the principle on which it is made and used is very much the same as the micrometer calliper. For trying whether one piece will fit another, without caring to know just how many inches, or


SETTING OUTSIDE CALLIPERS.

parts of an inch, either of them measure, the common callipers are used. Here you see the form of callipers sold in the stores, and called "spring callipers." But many workmen prefer the old style of "inside" and "outside" callipers; the inside ones being for taking the diameters of holes, recesses, or bores, and the outside ones for plug-shaped work. The two legs have a joint so that they can be set to just touch the work, the outside ones being tried on the work, as you see, and the inside ones are set in a similar manner. When both pairs of callipers are thus set, they are tried together to see if their points will just touch, and if they do it is known that one piece will go into the other. For measuring small work the callipers are held differently from the way for large work, as you see. There are many other measuring tools and instruments used in the requirements of the workshop, but these are sufficient to give you an idea of how closely we measure, and the tools we do it with.



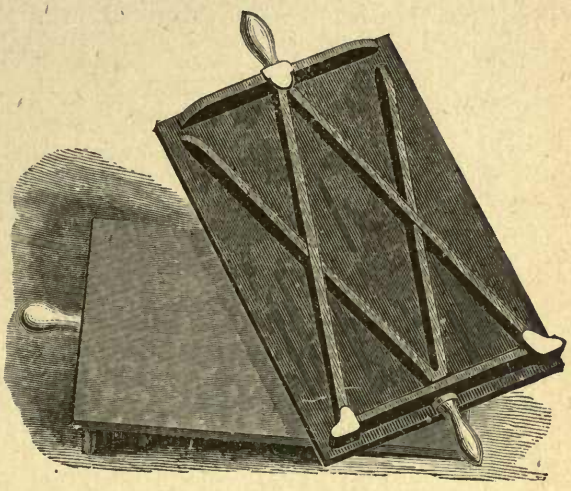
HOLDING CALLIPERS FOR MEASURING SMALL WORK.



HOLDING CALLIPERS FOR LARGE WORK.

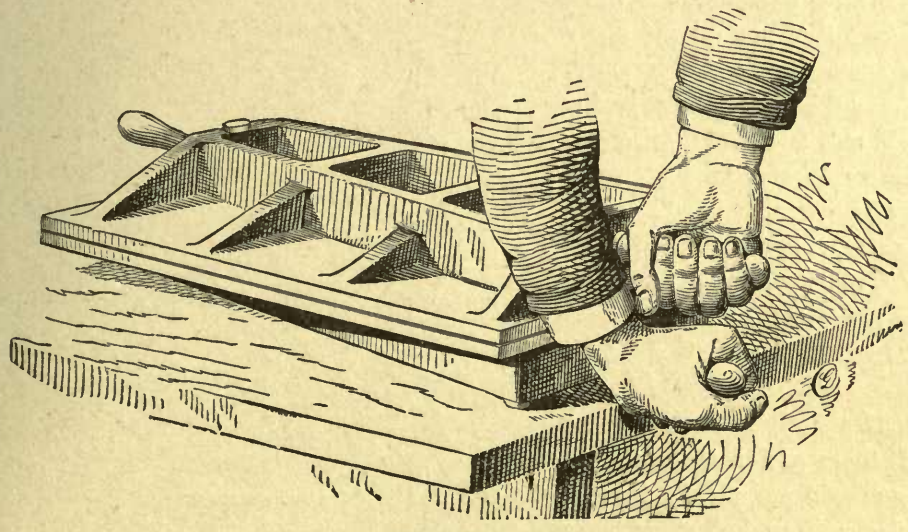
There are also many other interesting tools that man uses to test his work with, and

among these is the "surface plate," which is used to test if a surface is perfectly flat or not. The plate itself is made truly flat by a peculiar hand process which we need not explain here, and is laid upon the work to test it. Perhaps you will be able to form some idea of how wonderfully true or flat these plates are made, when you are told that they may be made to fit so closely together as to exclude the atmosphere from between their faces when two of them are put together by sliding one over the other, and, as a consequence, the atmosphere presses them together so hard that it is very difficult to slide the top one fully over the bottom one.



THE SURFACE PLATE.

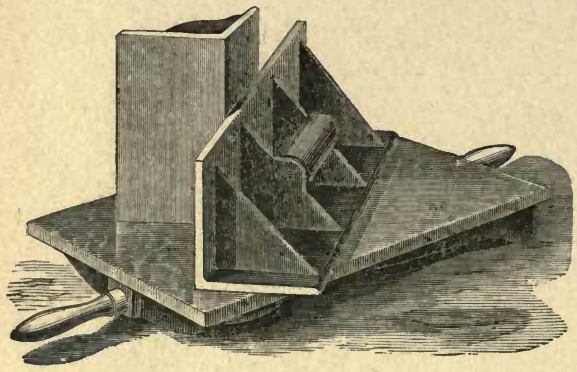
But there is another thing about these plates that is still more curious and surprising, and that teaches us a most useful lesson, which is that the most solid and stiff piece of iron bends very easily. It bends very little, so little, indeed, that you cannot see it, although you can find out that it does bend, which is proved in this way. Here you see two surface plates put together, and with handles in their ends. Now, if these plates were a foot square, and were a close enough fit, which they may easily be made, a strong man could



THE SURFACE PLATE.

not slide one on the top of the other, on account of the air resting on the top plate and pressing the plates together. And I doubt if two men could do it, for it would take about four hundred and fifty pounds, which is not so much to lift as it is to pull or push. But

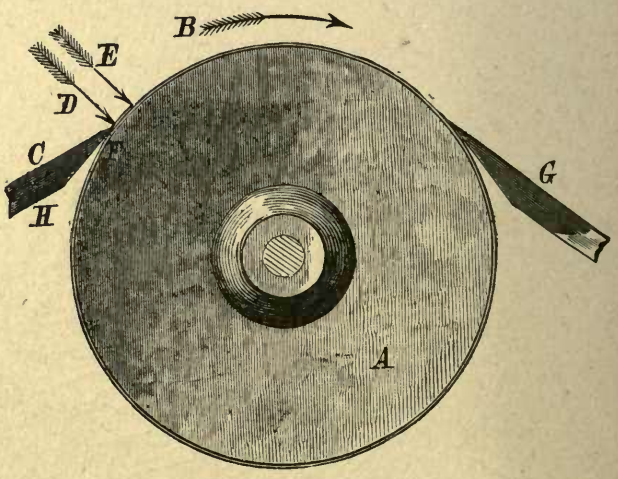
if, instead of the man trying to get the plates apart by pushing one off the other, he tries to pull them apart, he can do so quite easily, because the iron bends, even though it is an inch thick, and it will unlap and let the air in between the surfaces. You will see what I mean by unlapping if you take two sheets of wet writing-paper and put them together, and if you then take hold of two corners and pull them apart they will bend and unlap just as iron plates do.



ANGLE SURFACE PLATES.

If, the next time you see a piece of machinery, you take particular notice, you will discover that both in its framing and in its moving mechanism the horizontal and vertical line is adhered to as far as possible. That is to say, the length of its framing and the points where it is bolted together, and also the motion of the various parts, are nearly all in either a horizontal or a vertical plane or direction, so that they are at a right angle one to the other; and it is, therefore, essential to provide some special tools to test surfaces for being at a right angle, so we have the angle surface plates as well as the flat one, which are more accurate than the ordinary try-square.

Now we come to our common and most useful friend, the grindstone for tool-sharpening. We find it everywhere, even in the farmer's barnyard. But there are many things about even so common a thing as a grindstone that you are not likely to have learned. Such, for instance, as that the softer the stone is the faster it will cut, and that letting one side of the stone rest in the trough when there is water in it will water-soak the stone, soften it on that side, and cause it to wear away faster and so get the stone out of round.



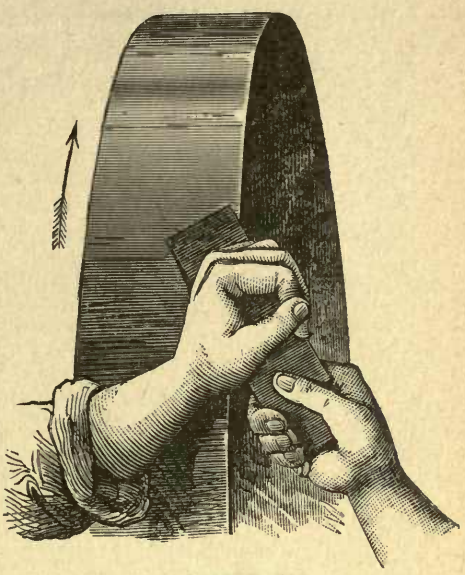
TOOL GRINDING.

You must know that a grindstone is composed of grains of sand or stone, and that it is the angles or corners of these grains that make it cut, and you will see plainly than in a hard and closely packed stone these grains will cling to the body of the stone even after the sharp corners are worn off. But if the stone is soft, the grains rub off more easily, and fresh grains with their unworn angles are constantly coming into use. Now, water softens the stone for one thing and washes away the metal cuttings for another, so that on the wet side there is every

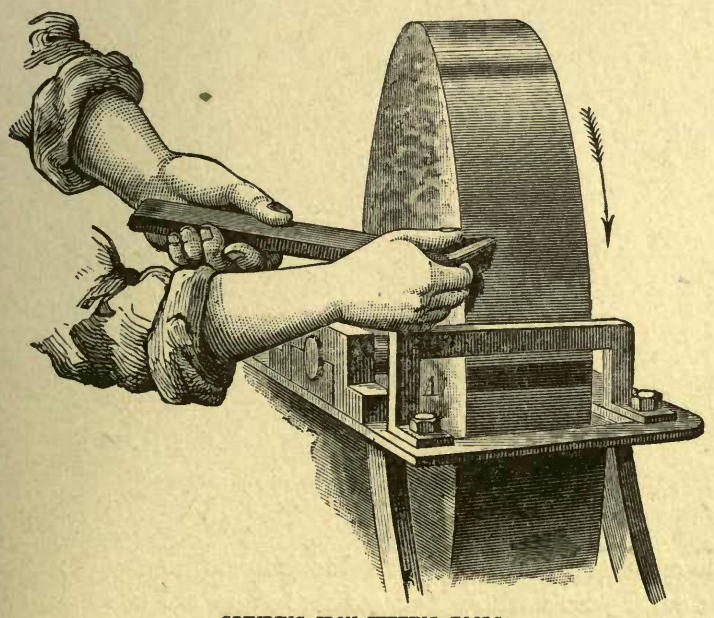
inducement for the stone both to cut and wear away. But on the dry side it will cut while the surface is clean, but it will soon get coated with metal, and then it will neither cut nor wear away. So you see how important it is to wet the stone all over when you are using it.

Carpenters generally stand on one side of the stone and machinists on the other, and you may as well know why they do so, for mechanics do not do anything without a reason.

Suppose that we have a stone running around in the direction of the arrow B, and the carpenter will hold his chisel or plane blade as at C, because he could, on an ordinary grindstone, hold it steadier than he could if he held it at G. This is always the case, even in a true or even-running stone, but by grinding in position C, the tool has a feather edge produced on it, this being a ragged edge shown extending from D to E. If he holds the chisel at G no feather edge will be made; so that the carpenter can grind his tools better when the stone runs towards him, providing that it runs true, so that he can hold the tool steady. But as this not often the case, he is generally obliged to stand on the other side of the stone. The way the carpenter holds a tool, such as a plane blade, is at an angle, as you see, and as the face of the stone wears out of straight he moves the blade very slowly across the stone, holding it all the while as steadily as he possibly can, so as to grind a good even and flat face upon it. The machinist requires an iron rest to support his hands as he firmly presses the tool to the grindstone.



TOOL-GRINDING.

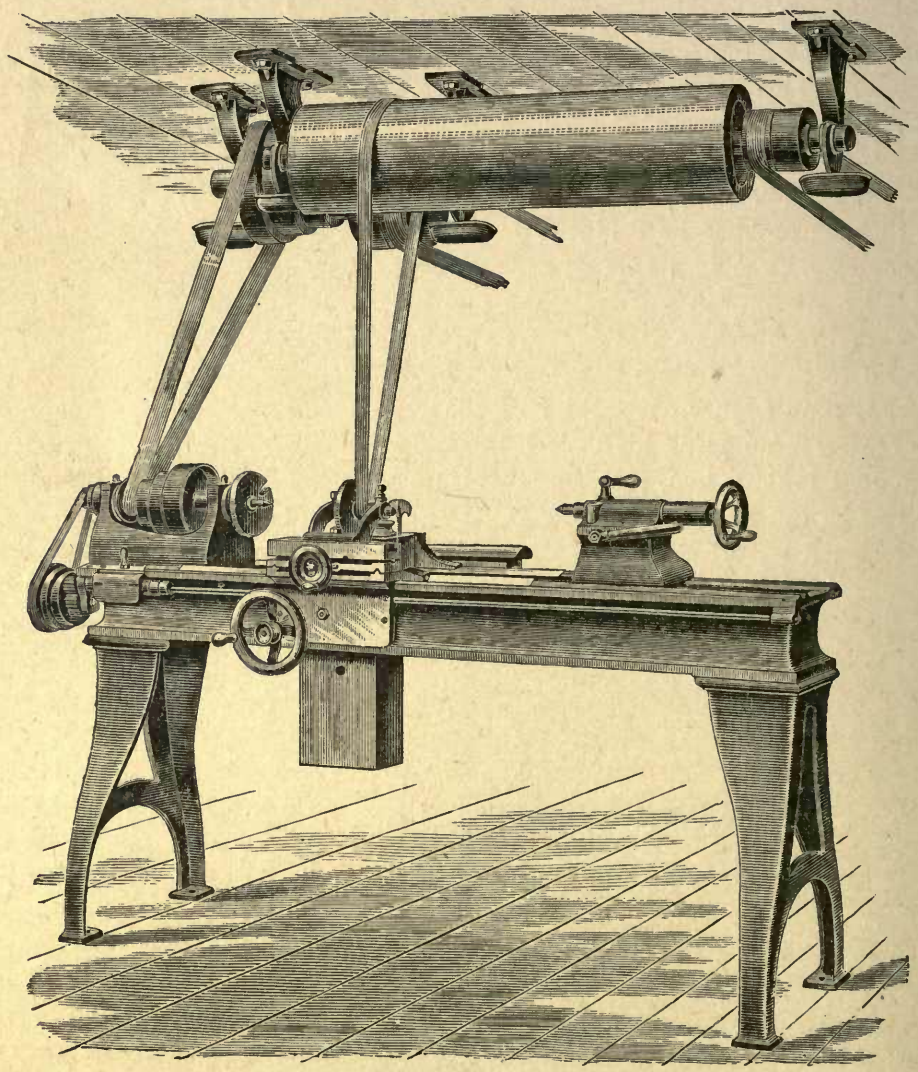


GRINDING IRON-CUTTING TOOLS.

The grindstone, which has been sole monarch of our tool-sharpening tools, has now, however, a very formidable rival in the emery-wheel, which is made by pressing grain emery, mixed with some cementing material, into a mould under a tremendous pressure. The emery-wheel can be run much faster than the grindstone, and especially in small and thin

wheels. Another thing is, that it can be made to any required shape by simply fixing the mould it is pressed in to suit the shape wanted. Harness and cutlery makers, as well as stove-makers and machinists, find the emery-wheel a splendid grinding tool.

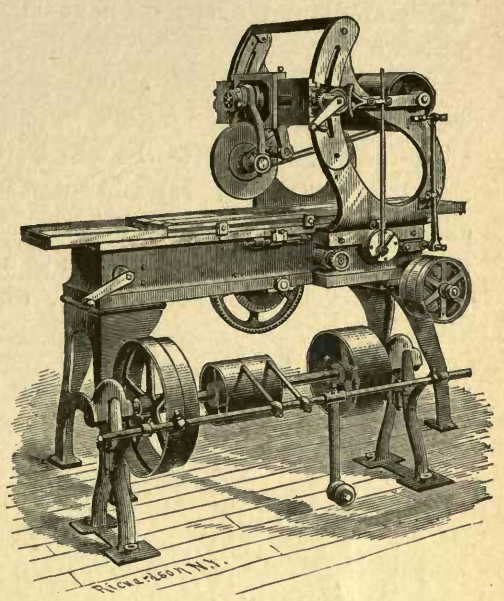
In every trade where emery-wheels are used, you will find a different kind of emery-wheel grinding machine. Here, for example, you see an emery grinding lathe, an emery-wheel being used instead of a steel cutting-tool.



AN EMERY-WHEEL GRINDING-LATHE.

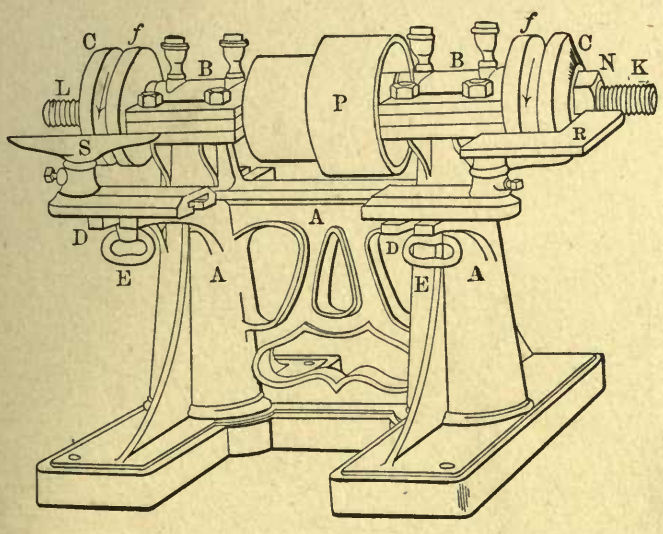
The object is, in this case, to cut metal too hard for steel tools to cut, or else to make more true and smooth work than cutting-tools will. You see that there are two belts or straps—one driving the lathe and the other the little emery-wheel, which runs two or three thousand revolutions in a minute, while the work runs slowly, at say not more than two hundred.

This machine can be used for round or cylindrical work only. For flat work we have quite a different shaped machine, which is, you will notice, very much like an iron-planing machine, with an emery-wheel in place of the cutting-tool. The emery-wheels will not, in any of these machines, cut ordinary metal as quickly as a steel cutting-tool, but this is more than made up by the extra smoothness. The work is fastened on the table, which glides back and forth under the wheel, but you must know that the wheel only cuts while the table is moving in one direction, which is that in which the wheel acts to push the work away and not pull it along, for in that case the grinding would not be done steadily and smoothly.

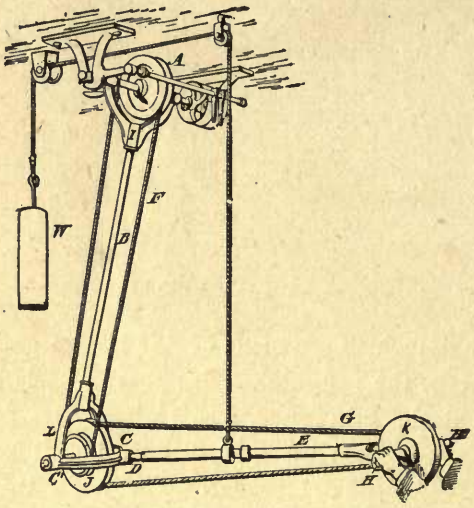


THE EMERY GRINDER FOR FLAT SURFACES.

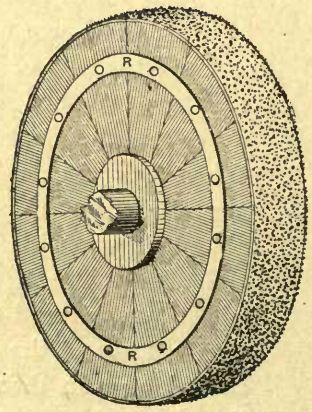
For such grinding as is done by holding the work in the hands, the machine usually has two emery-wheels, and rests such as R and S are used to support the work. P is the pulley that drives the wheels, and you may judge how fast these wheels revolve when I tell you that if they were let run along the ground they would travel very nearly a mile in a minute. Those wheels which are made of the largest grained or coarsest emery cut the quickest, and, of course, the roughest. But these wheels may be soft or hard, and, just as you were told about the grindstone, a soft wheel cuts faster than a hard one, but it wears out sooner. The main trouble in using a hard emery-wheel is, that it what is called "gums" or glazes, which means that the angles of the emery wear smooth and the particles of metal stick on the wheel and clog it up, which prevents it from cutting. When this occurs the wheels must be either cleaned or the glaze cut off with a diamond tool. Some kinds of emery-wheels can be used as large as, and in place of, the grindstone, and I have seen them swung in the air on frames so that they could be moved over the uppermost surface of iron plates, such as are used to make bankers' safes, grinding off the scale and smoothing the plate so that it will look well



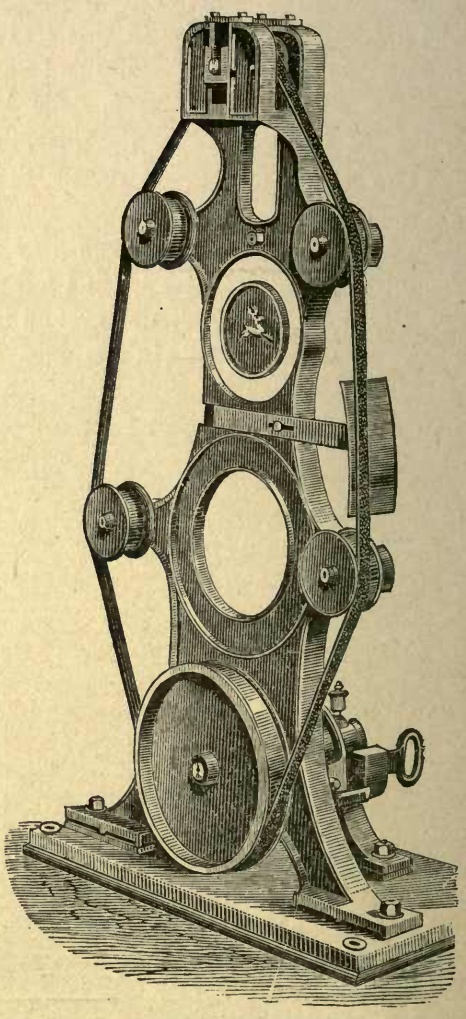
when it is painted. A similar frame is used in some foundries to clean the rough places off castings, th whole frame being suspended at A, and balanced by a weight W. There are two sections or links in the frame, one standing vertically and the other horizontally, and there are two driving belts, one at F and another at G. There are at C and at H a series of pivoted points that permit the emery-wheel to be swung sideways or moved in any direction, so that the man takes hold of two handles (one on each side of the wheel), and moves the wheel around and about the casting, grinding off the rough and sandy surface. It is really curious to see such a wheel at work, for it may be so turned about and so held that the driving belt is twisted, and you would not, unless you saw it, think that it could drive the wheel at all, but the thick and fast flying sparks would soon undeceive you, and show that the wheel was hard at work gnawing away at the iron.



EMERY-WHEEL SWING-FRAME.



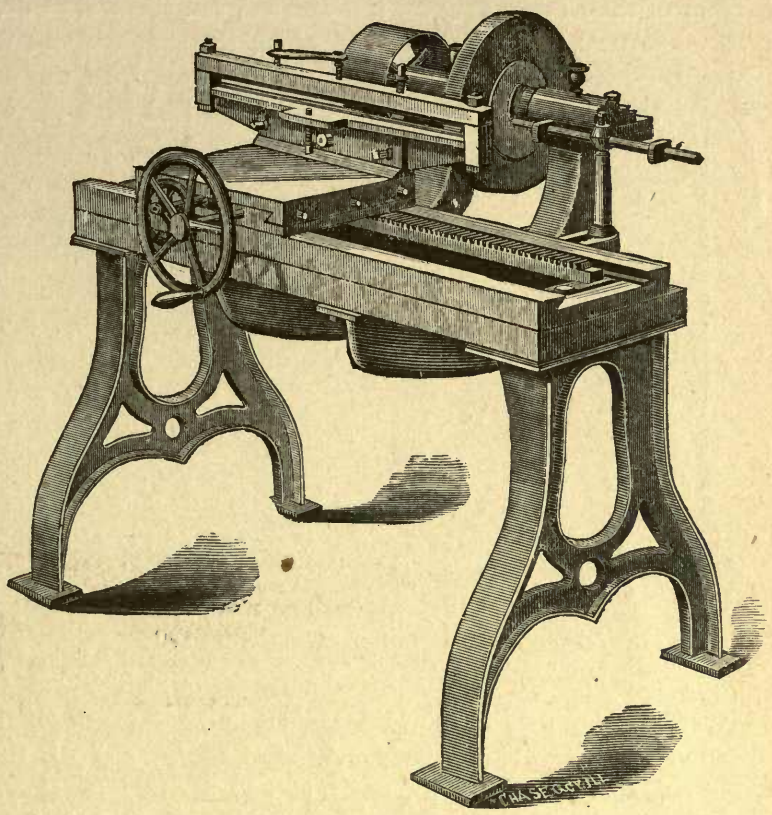
A POLISHING WHEEL.



AN EMERY BELT MACHINE.

The most refined uses of the emery-wheel are grinding the cutters for milling-machines, in grinding flat surfaces, and in its application to the grinding-lathe; and next to these comes

its use for grinding tools and cutters. Here we have an emery-wheel grinding machine for sharpening the knives of wood-planing machines. The knife is held in the frame in front of the wheel, and this frame travels back and forth past the wheel so as to bring all parts of the knife-edge in contact with the wheel face, which cuts continuously. The hand wheel is to move the knife towards the emery-wheel and thus put on the cut. As the frame that carries the knife is moved back and forth in a straight line, the edge of the knife is sure to be ground straight.

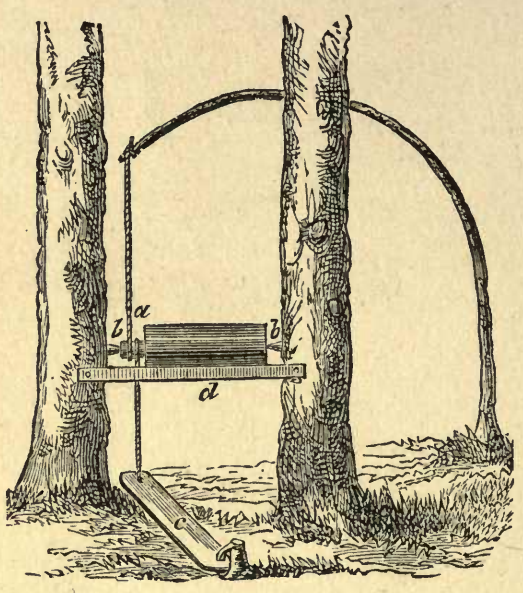


PLANING-MACHINE KNIFE-GRINDER.

If you put on your thinking-cap for a minute or two, you will see that grinding and polishing are very similar operations; the finest kind of grinding constituting a polishing process so far as metal work is concerned. And so it comes about that the first stages of polishing are done with fine emery, and the final stages with other and finer polishing powders. But, for polishing purposes, a wooden wheel covered with leather on which emery is glued is used. And the more the emery gets used the finer it will polish. Some of these wheels are covered with lead, while all of them run at a speed of about a mile in a minute. Other kinds of polishing wheels are made of round pieces of rags put side by side until they make a wheel about an inch thick. You would think that a rag-wheel would be a very limp affair, especially as the layers are all loose, except at the centre, where they are bound together, but the high speed at which they revolve causes them to stand out straight like a wooden wheel, and they actually require considerable pushing to bend them sideways. A rag-wheel not only polishes very beautifully, but it will go into all the little crooks and corners where a solid wheel could not get.

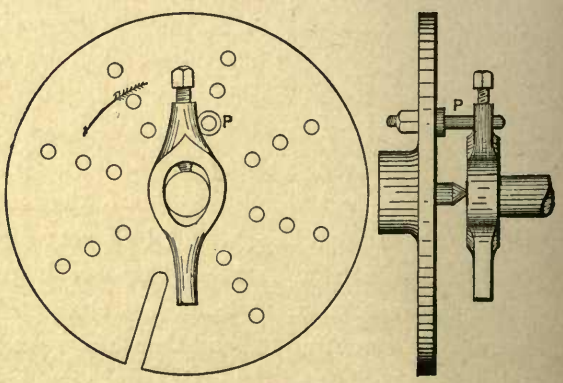
The brass finisher uses emery belts as well as wheels, the outside of the belt being coated with glue and emery. The belt is driven at a high speed over pulley, as you see. He holds the work against the belt and turns it about so as to dress all the surface. But the final polishing he does with buff-wheels, rag-wheels, etc., which polish smoother than the emery belt.

Of all the machines that man has constructed, none is so interesting and important as the lathe, which is found in some one of its many forms in almost every workshop. Some of these forms are very intricate and complicated, so that, although it is easy enough to understand the principle upon which the simple foot-lathe of our forefathers works, yet from the many self-feeding mechanisms that have in recent years been added to the lathe, and the numerous forms it has been made in to suit particular kinds of work, it would require a very large volume to describe even one lathe of a kind and its principal mechanisms. At the Vienna International Exhibition there were exhibited vases and other similar articles of wood turned by the Hercules, the remnants of an ancient Asiatic nation which had settled at the time of the general migration of nations in the most remote parts of Galicia, in the dense forests of the Carpathian Mountains, and the lathe used to produce these vases is, as you see, composed of two wooden plugs, *b b*, whose pointed ends support the piece of wood, *a*, which is cut to shape or *turned*, as it is called, by tools held in the workman's hands, and rested on the bar *d*. A cord tied to the end of a sapling passes around one end of the work and is tied to the treadle, *c*, by operating which the work is revolved backward and forward on the supporting centres *b b*. A very rude contrivance, you will say, and so it is, but our forefathers produced some beautiful work on just such rude lathes.

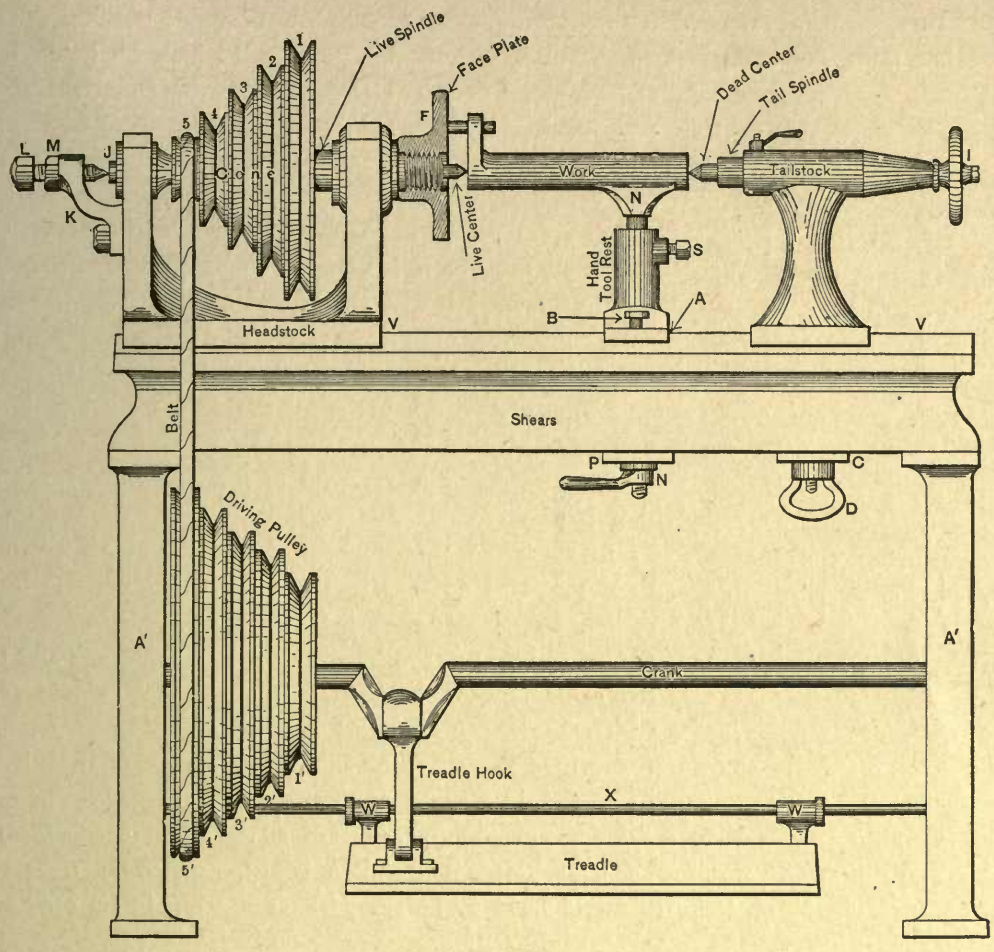


ANCIENT LATHE.

The simplest lathe that is used in civilized countries is the foot-lathe, the names of its parts being marked near them; and it is easy to see that by operating the treadle the driving pulley causes the belt to revolve the cone continuously in one direction, and that the pin F drives the work which is held between the "live" and "dead centre." You will perhaps think the words *live* and *dead* curious ones to apply to pieces of mechanism, but they are not altogether out of place, because the live centre is the one that revolves, while the dead one remains motionless. The piece of work we have shown in the lathe has luckily an arm on it, and that comes in very handily for the pin F in the face-plate to drive, but this would not often be the case, and the workman has to resort to all sorts of curious contrivances to drive it. The simplest

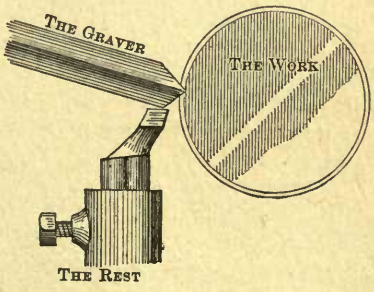


LATHE DOG.



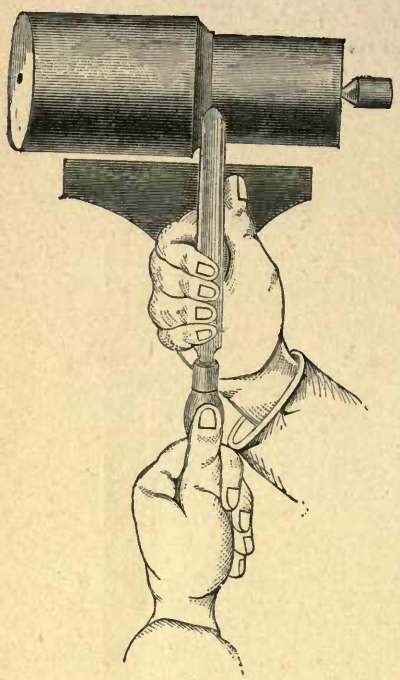
FOOT-LATHE.

of these is called a *dog*, a *driver*, or a *carrier*, the first two being the American, and the last the English name. The name *dog* was doubtless given from the action of the screw, which bites the work, and the names carrier or driver from the action of carrying or driving the work.



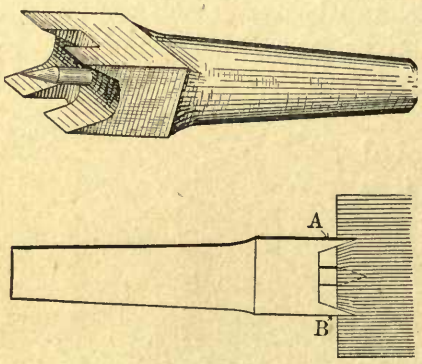
To return to our lathe, however. The shears or bed used, in ancient times, to be made of wood, but it is now made of iron; and while the resting piece N was in olden times the only means of supporting the cutting-tools, there are now many other means of holding, moving, and adjusting them, as we shall see presently. The work is cut to shape in foot-lathes of this kind by pressing the cutting edges of the tools against the revolving work, as we see in the case of the graver, which, sharp-pointed though it is, can be made to turn work having curves, sweeps, and beads of all shapes and sizes upon it. A marvellous tool, indeed, is this graver, for it is used for all kinds of materials, except, perhaps,

wood, and is held in many different positions to accomplish different results. The wood-worker finds, however, just as useful a tool in the "gouge," which he holds just as you see, moving it along the work, and twisting it and turning it from side to side at all sorts of angles and positions with relation to the work, with a dexterity and ease that seem wonderful enough to look at, but which seem really marvellous to one who first attempts to use it, because if it happens to be presented improperly to the work it will rip in and be wrenched violently from the hands, very often tearing or splitting the work, and throwing it out of the lathe.

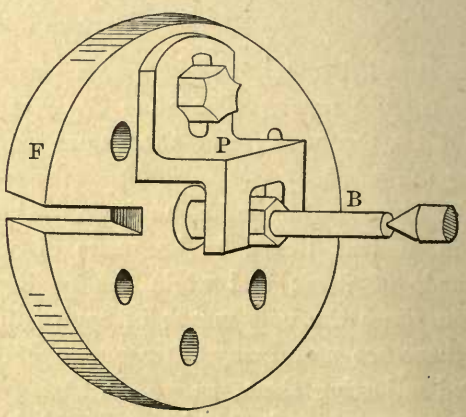


WOOD-TURNING.

The wood-worker scorns the live centre and the dog or carrier of the iron-worker, because it takes too long to adjust. The material of his work is a soft one, that is easy to cut. His lathe revolves a thousand times to fifty of the iron-worker's lathe, while his cutting-tools move so quickly that his hands are constantly in action, so that expedition becomes a sort of second nature to him; hence he removes the face-plate and the live centre, and replaces the latter with a "fork-centre," which has a central point to hold the work true, and two wings to sink into the wood and drive it. Even in so simple a thing as this fork-centre, quite some care must be taken to enable it to serve its purpose to the best advantage. Suppose, for example, that the point was not central between the two wings, and every time the work was replaced in the lathe it would have to be set with each wing to its own seat



A FORK-CENTRE.

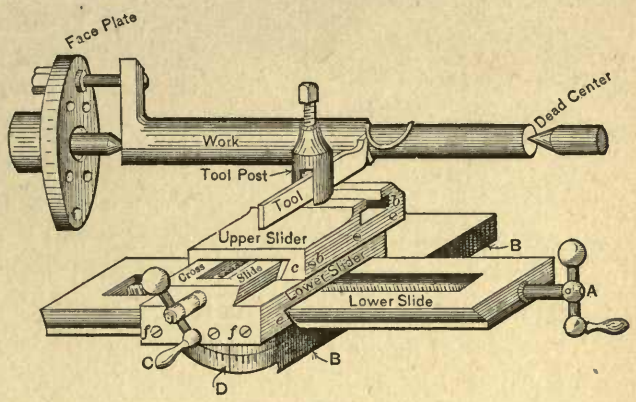


THE IRON-WORKER'S BOLT-DRIVER.

in the end of the work, or else the work would not *run true*, as it is called. Another point is that by making the wings straight on their sides, A, B, there is no tendency to split the work, while by tapering the inside of each wing it tends to close the wood upon

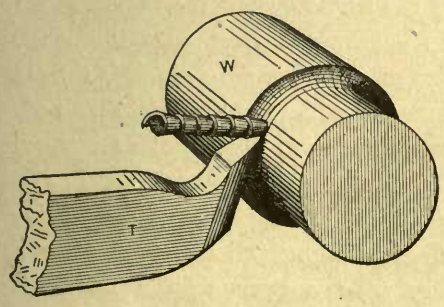
the central point, and thus cause it to hold the work more firmly. The expert workman has in every tool or appliance he uses or constructs simple little elements of this kind to consider, obtaining widely different results from very slight, and in some cases almost imperceptible, differences in the shape or method of using the implements of his trade.

The iron-turner, who may justly be termed the king of metal-cutters, also has his simple contrivances to save time in driving the work in the lathe, and one of the most serviceable of them is the bolt-driving plate P, which is fastened to the face-plate, and fits over the sides of the head of the bolt to be turned, so that by passing the bolt-head between the jaws of the plate the *dog* is dispensed with.



THE SLIDE-REST.

The hand-lathe, such as we have been describing, holds, however, but a very insignificant position in the great family of lathes, the greater part of its duty being done by either slide-rests or "self-acting" or "engine lathes," as they are termed in the United States. The lathe we have thus far made the acquaintance of is transformed into that much more useful tool, the slide-rest lathe, by simply providing it with a slide-rest to carry the cutting-tool instead of holding it in the hands. The lower "slider" is caused to move along the lower "slide" by operating the handle A. The upper "slider" is moved along the "cross-slide" by the handle C, and the cutting-tool is fastened in the tool-post and caused to move along and about the work by revolving these two handles, the slide-rest being held firmly by bolting its base, B, to the lathe shears. Instead of the short, slight cuttings made by the hand-tool, we are now enabled to take off the work coarse, strong cuttings or shavings that may be made as much as a hundred feet long, when the material is soft wrought-iron, without seams or black spots. It may seem strange to speak of seams and black spots in polished iron, but if iron is but sufficiently polished it is found to contain numerous jet-black streaks and spots that do not appear under ordinary circumstances.

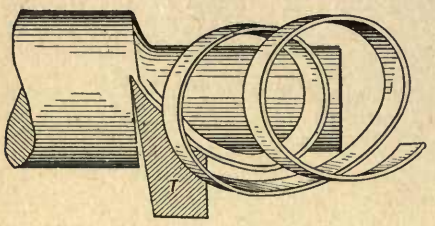


CUTTING STEEL.

The shape of the cuttings or shavings produced by a slide-rest tool vary with the hardness of the metal as well as with the shape of the tool. Hard steel curls up closely as you see, the coils binding close together, while soft wrought-iron peels off, when cut by a sharp tool, in smooth open coils, that wind round and round as they leave the tool-point.

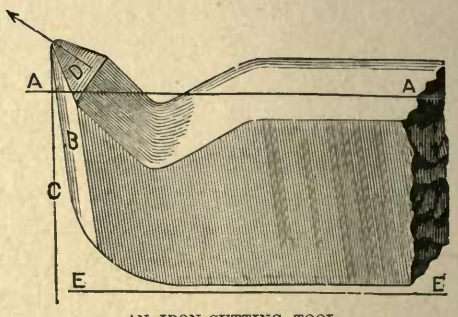
The tool itself, you will observe, is a simple affair, merely a piece of tool-steel forged into shape, and having its faces B and D ground smooth, so as to produce sharp-cutting

edges at the edges of face D. Its capacity to cut is produced by what is called "hardening" it, which consists of simply heating it red-hot and plunging it into water, this sudden cooling making it as hard as glass, and as, throughout all nature, a hard substance will cut a softer one, so will hardened steel cut soft steel. All that is necessary is to apply sufficient force, and it does not matter what the shape of the tool may be it will sink into the softer material. But to enable the slide-rest tool to cut easily and quickly it must have a sharp edge, and it is quite astonishing how long such an edge will last if the work is revolved slow enough. Hundreds of feet of shaving can be cut off without grinding the tool, especially if water is used to keep the tool cool, but if it gets hot the sharp edge is soon destroyed.



CUTTING WROUGHT-IRON.

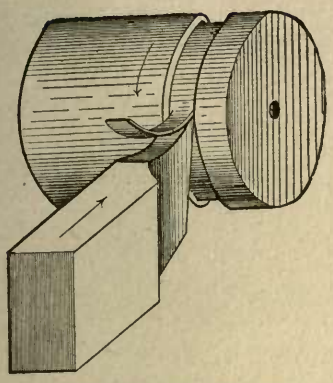
The different shapes of tools used by the turner are numbered by the hundreds, every different metal requiring a differently formed tool. Sometimes the eye will not readily perceive the variation of form between two tools, of which one will cut a certain metal sweetly and easily, while the other would squeak, rub, and grind, and show its uselessness in a dozen different ways. The ancients made their cutting-tools of copper, which they were able to harden, but this hardening process has become a lost art, and steel alone is our material for cutting-tools. But steel will plough its way through any of the metals, and is on that account more valuable to man than gold, silver, and all the precious stones put together.



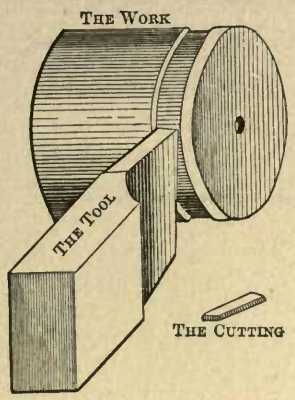
AN IRON-CUTTING TOOL.

If we were called upon for advice as to what would be the best shape of tool to cut a bar of iron into two pieces in the lathe, or to cut a groove in it, or if we were asked how to shape a tool to "*square* up" or smooth the end of the bar, we should, unless we had seen such tools, find we had a difficult task before us; but once having seen the tools, we are surprised at their simplicity. Look at the cutting-off or grooving tool; it is simply a piece of steel narrowed at the end, and is pushed forward while the work is revolved. It cuts off a clean curled shaving, such as shown, on wrought-iron, soft steel, or copper, its top face being hollowed out. But for brass-work it must not be hollowed out, or it will tremble violently, or what the workman calls "chatter," leaving the surface of the work covered with hundreds of little diamond-shaped undulations, all arranged after a perfect pattern. To have a tool *chatter* is a sign of very poor workmanship, although it is quite difficult at times to prevent it. To face up the end of our shaft, the knife-tool or the *squaring-up* tool is used, being so shaped that its point may be moved close up to the dead centre.

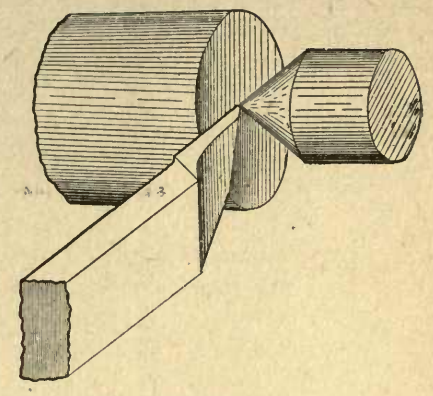
Now look how brass cuttings come off; they are little rough pieces, with sharp corners all about them; and if the work is revolved quickly, as it should be for brass, they will fly off at a great speed, and will be so hot that you cannot hold them in your



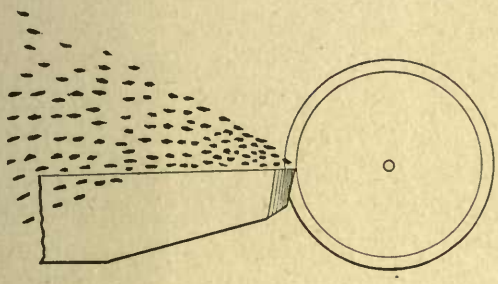
CUTTING-OFF TOOL FOR IRON.



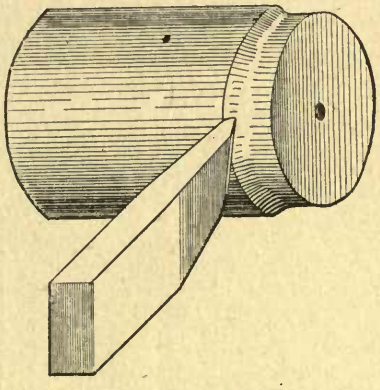
CUTTING-OFF TOOL FOR BRASS.



THE "SQUARING-UP" TOOL.



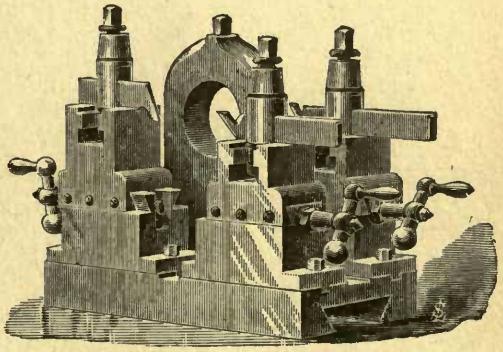
HOW BRASS CUTS OFF.



CUTTING-TOOL FOR BRASS.

TOOLS AND METAL CUTTINGS.

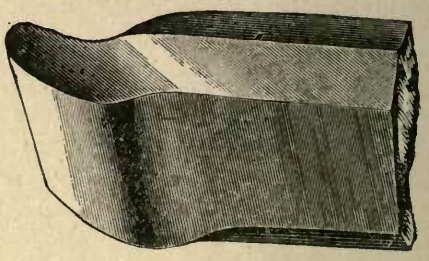
hand. But brass cuttings are too valuable to be allowed to fly all over the shop, and so the brass-turner puts a leather washer or pad upon the tool to stop them. In olden times the apprentice boys were given a penny a pound for all the brass turnings they made, and so they worked quickly and hard to make plenty of cuttings, but in our day wonderfully constructed machines do much of the work that formerly fell into the dexterous hands of the brass-turner.



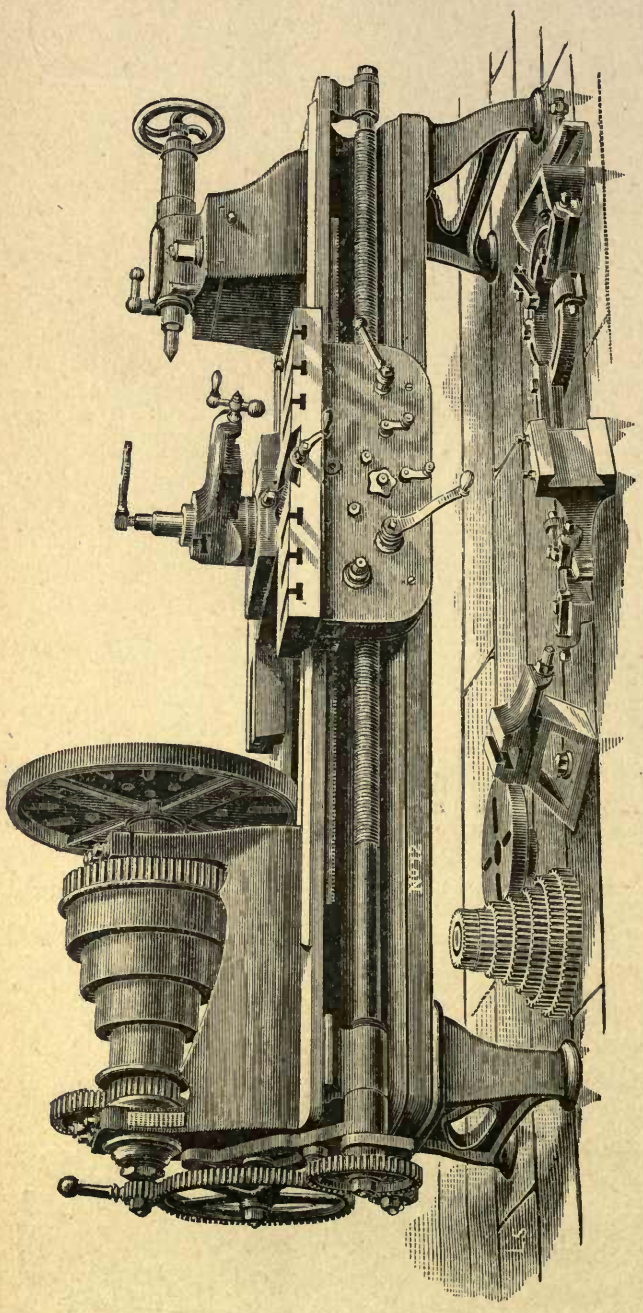
SLIDE-REST WITH THREE TOOLS.

Slide-rests do not always carry one tool only, but sometimes two or three, one being at the back of the rest and turned upside down, as you see. Such rests are used for long shafts or rods, the two tools on the left or front side of the rest preparing the work for the finishing cut, which is taken by the tool on the right.

Slide-rests of this kind are used upon what are called in England "*self-acting*," and in America, "*engine lathes*," in which the tool is moved to take its cut either along or across the work by automatic mechanism, which is nearly all hidden, so that it looks quite marvellous to see it moving along, cutting off the curled ribbons of iron without any apparent means



BORING-TOOL FOR IRON.



THE ENGINE LATHE.

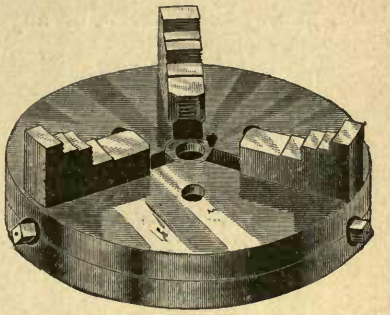
to cause the movement. All the tools we have thus far described are used in the engine lathe as well as in the slide-rest, and are for work that is held between the lathe centres, which the workman calls "*outside*" work, while that containing holes or bores he calls "inside" work, for which

BORING-TOOL FOR BRASS.

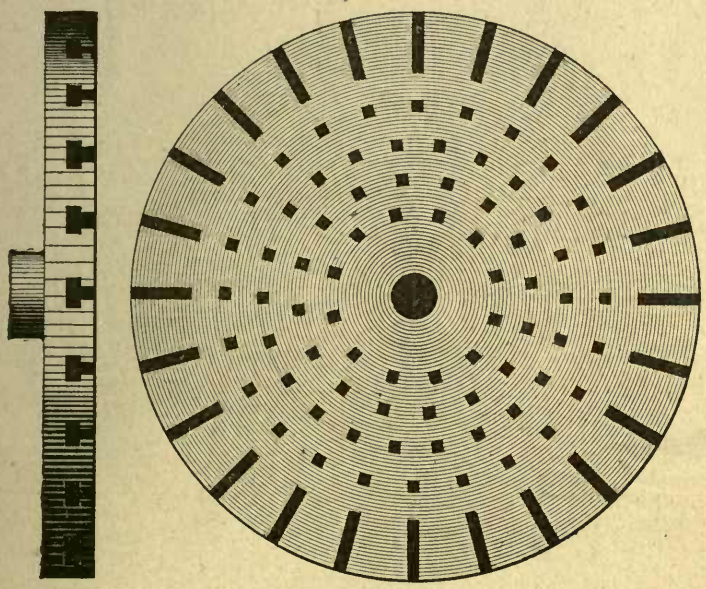
he uses various kinds and shapes of boring-tools, which are placed in the slide-rest in the position in which you see it.

The boring-tool for iron or steel is a sturdy fellow, who needs to be as chunky as he can be made, while the boring-tool for brass need not be either so sturdy or so sharp, but what he lacks in these respects he makes up in noise, for he delights in a heavy cut and a quick speed, and forces his way ahead with a half-rattling

and half-grumbling voice that seems to say, "See what a terrible fellow I am; hark, how I am tearing into this metal." But if you give him a light, easy task he is a terrible fellow to chatter, especially if you give him the least excuse to do so by inclining his face, A, upwards instead of downwards towards the point. You will see at once that in order to use these boring-tools the work must be held without the aid of the lathe centres, and so what are called chucks are used. The *bell* chuck was a great favorite of the old hand and slide-rest turners, but he is but little used now. He is a sturdy old fellow, and with his screws set firmly down upon the work would hold it tighter than our modern chucks, but like many other old-fashioned mechanical contrivances, his honesty did not make up for his slowness, and so he has had to give way to the Universal chuck, whose jaws all move together and *bite* the work. The gripping surface of each jaw is called its *bite*, but I must tell you that in very large chucks the jaws, or rather dogs, as they are called, are moved separately, the chuck being then called a "*dog chuck.*"



Sometimes, indeed, the chuck has neither dogs nor jaws, and then it is called a "chuck-plate," and the work is held to it by bolts and plates and other contrivances that are too numerous to mention.



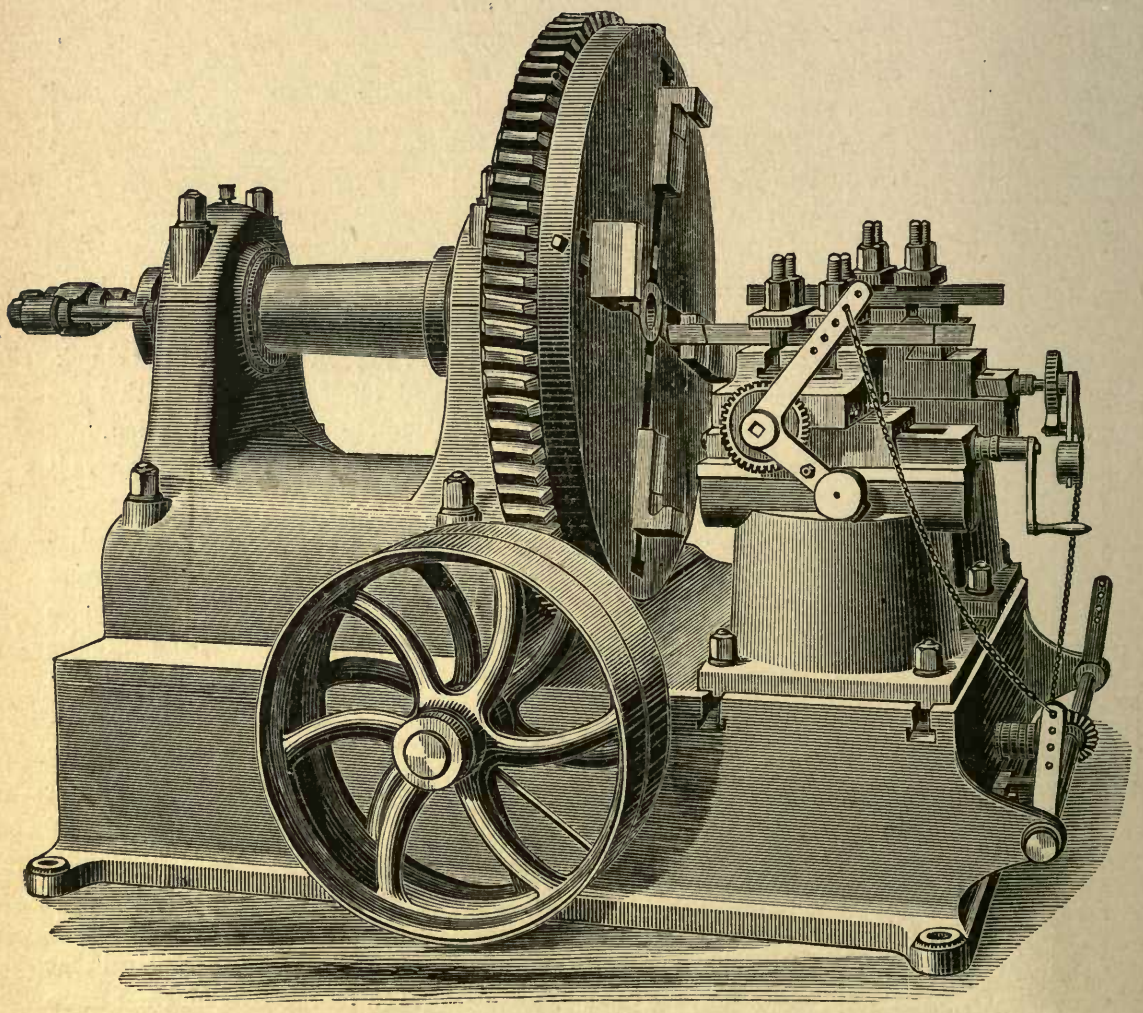
FACE PLATE.

These "chuck-plates" are used for all sizes of work, from the smallest to the largest, and it is found, in a great many cases, to require more skill to chuck or hold the work than it does to perform the cutting operations upon it. You will be surprised to hear the cause of this, because it does not seem at all likely that a small bolt and nut, weighing not more than half a pound, is capable of bending a bar of iron or steel that is a foot square, and not more than a yard long. Indeed, such a piece of metal will actually bend of its own weight; and so the greatest of carefulness and skill are necessary to chuck a large piece of work without bending it.

The chucking lathe is a short, chunky fellow, that sometimes has no "tailstock," as you see, giving him quite a bulldog look, as compared to the dainty engine lathe. Here you see there are two separate slide-rests; and I may tell you that in other forms, as, for

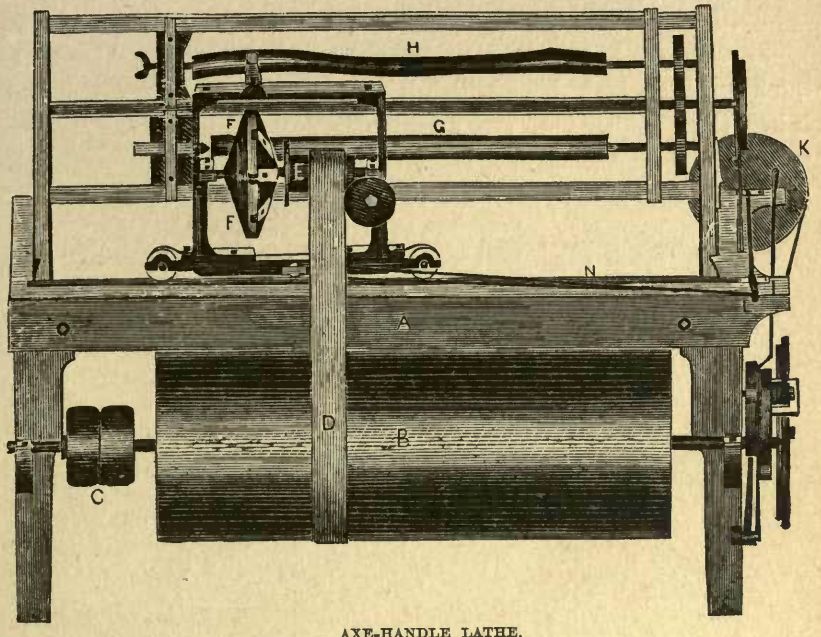
example, in the lathes for turning the crank-axles for locomotives, the reare five or six, all carrying cutting-tools at work at the same time.

Let us now make the acquaintance of some others of the many curious forms of the lathe. Here, for instance, we have an example of what appears to be the most erratic member of the lathe family, namely, the axe-handle lathe, which can be used to turn shoe-lasts, gun or rifle stocks, or any other oddly shaped piece of wood-work. In the common



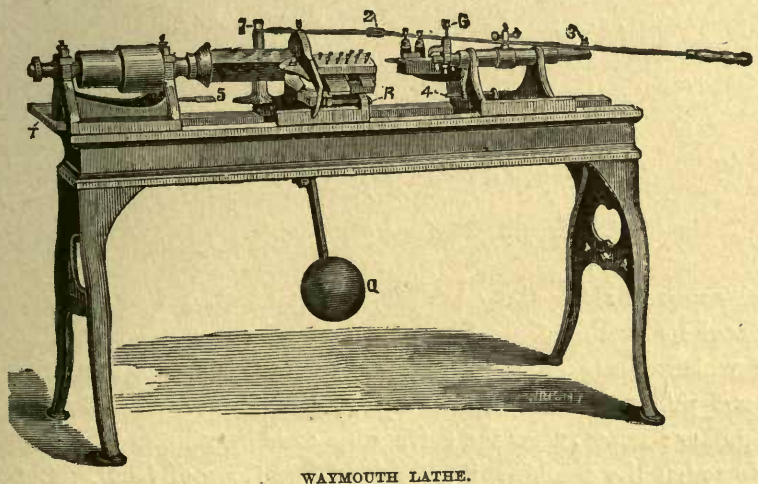
wood-turner's lathe the work flies around so fast that you cannot see it move; while the cutting-tool moves comparatively slowly, but here all this is exactly reversed, for the cutting-tool whirls around so fast that you cannot see what it is, while the work revolves quite slowly. The principle upon which this odd-looking lathe works is an exceedingly simple one, for it merely copies the shape of whatever piece of work you put into it; nor will you find it at all difficult to understand how this is done. First, we see pulleys at c that are driven

by a strap or belt, and one of which drives the "drum" B. From B a belt D drives a pulley E, which in turn drives ahead H, to which is fastened the cutting-tools. H is a finished axe-handle, and G is a piece of wood to be cut to the same shape as H; these two pieces being revolved about twenty turns a minute. The frame that carries the cutter-head F travels on wheels, resting on the frame A, and at the top it rests against the finished axe-handle H, so that as H revolves it rocks the frame carrying the tools F, and causes them to cut G to the same shape as H. The carriage is moved slowly along as the cutting proceeds, so that the cutters finish the work in passing once along it.



AXE-HANDLE LATHE.

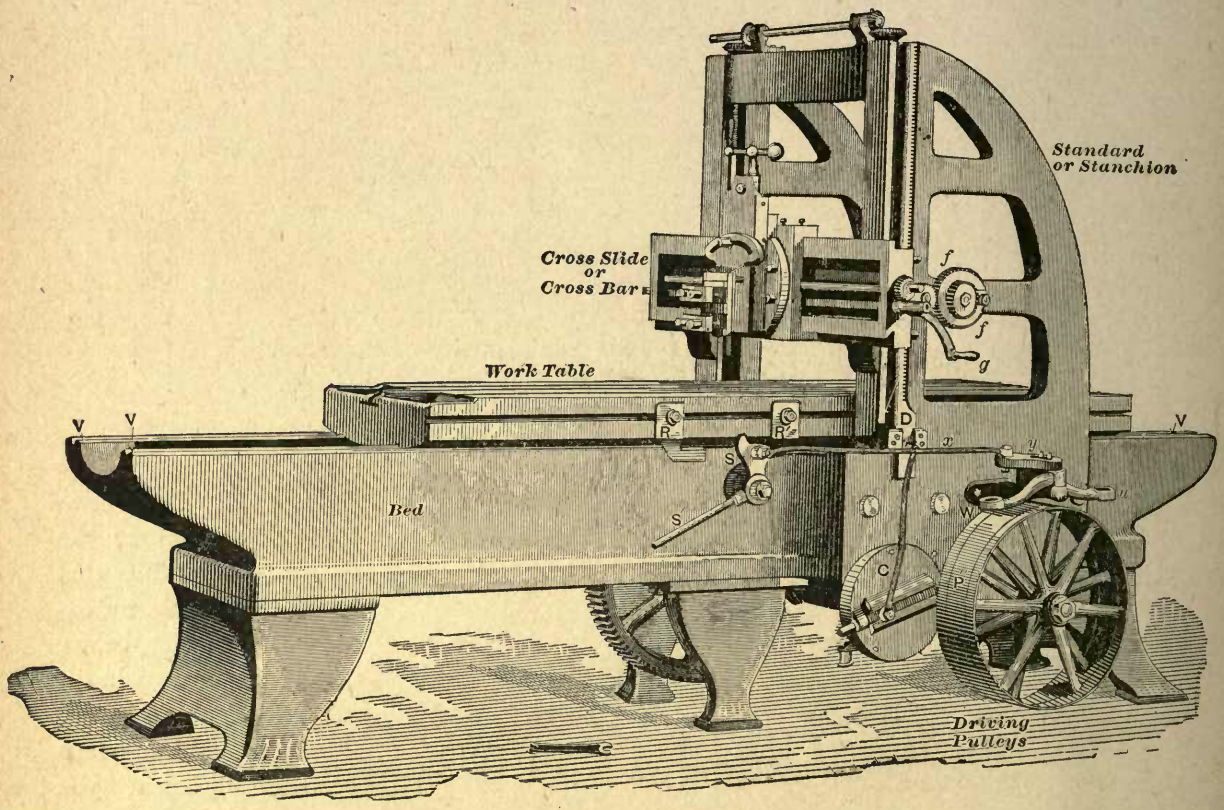
There is one more wood-worker's lathe, called the Waymouth lathe, that we must make the acquaintance of, because he is such an active little fellow and makes so many things that we all use. Such, for example, as wooden boxes, toy-carriages, wheels, wooden balls, and so on. If you watch him make wooden pill-boxes, you will see that he cuts them out of the solid wood one after another with great rapidity, and that he makes them all just alike, with the lids all a close, neat fit, without any measuring after he has been once set. The workman puts a square stick of wood in the lathe and simply pulls the long handle, first in one direction and then in another, and brings, in one way and another, four different sets



WAYMOUTH LATHE.

of tools to work one after the other, and finally, by pressing his knee against the pad *a*, the finished work is cut off. What would strike you as most funny is that the workman has to use both hands and arms, as well as his knee, and as these movements are repeated rapidly, he looks like a long-legged spider stretching out his arms and legs in all directions.

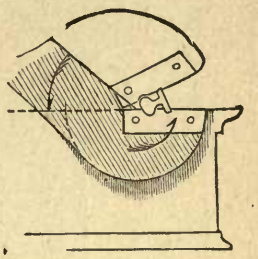
Next to the lathe the most important iron-cutting machine-tool is the planing-machine, which consists of a bed, on which is a table that slides back and forth with the work bolted on it. On each side of the machine is a "standard" or "stanchion," which carries a "cross-bar," on which is a head that carries the cutting-tool. By means of self-acting



THE IRON-PLANING MACHINE.

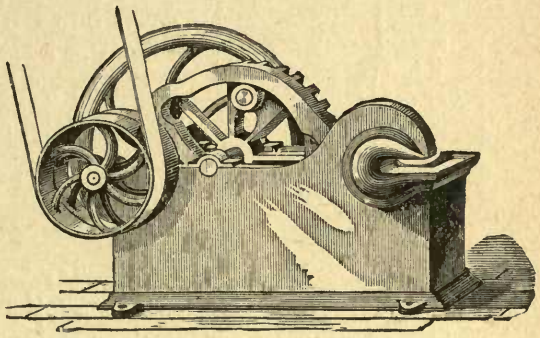
mechanism this head is gradually moved along the cross-bar, taking one step forward each time the work-table has reversed its motion from a backward to a forward stroke. The machine is driven by a belt which passes over the driving pulleys, and is moved (by automatic mechanism) from one pulley to the other in order to reverse the direction of table-motion, or to stop it altogether; hence, after the cutting has once begun, the workman has nothing more to do than to watch the machine, because it will go along of itself. But this does not in any way detract from the skill required to work such a machine, because the shaping of the tool, the method of holding the work, and the rate of the cutting-feed are matters left entirely to the workman's judgment; and these are points that require the

utmost thought and carefulness to produce the best and the quickest results. Iron-planing machines are made in various forms : the one we are describing stands upon legs, as all the small ones do, but the large ones require to rest upon a solid foundation, and carry two, and sometimes three, cutting-tools which may all be used at the same time. Some are made to cut while the work travels back as well as while it is going forward, the cutting-tool turning around every time the table reverses its motion, and being actuated by a piece of mechanism that is called "Jim Crow," I suppose because its sudden motion in turning about suggested the nursery rhyme of



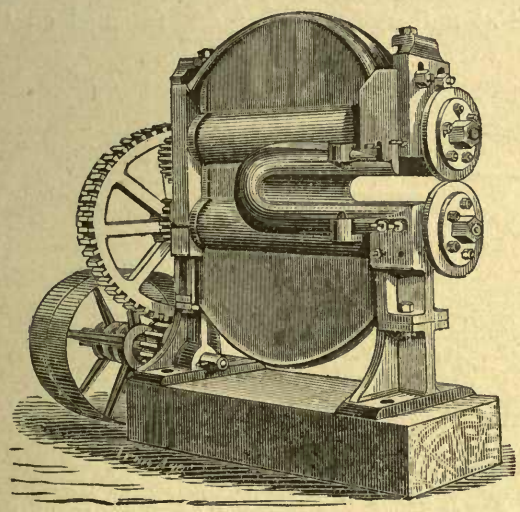
"Wheel about and turn about and jump, Jim Crow."

The massive appearance of the large planing-machine, and the deliberate manner in which his table crawls along, gives you the idea that he is a very strong and merciless fellow, and so indeed he is. But as he cuts on one stroke only he has quite some time to rest himself and let the tool get cool (for a tool always gets warm or hot to some extent when it cuts metal), and if you compare his action to that of a heavy lathe or to a pair of shears he does not seem to be such a terrible fellow after all.



A PAIR OF SHEARS.

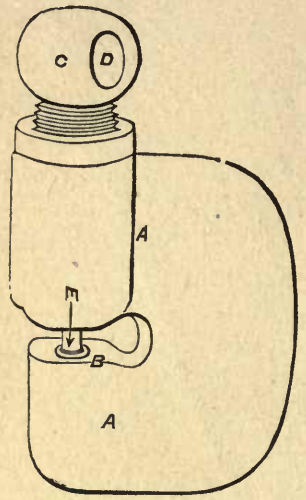
But perhaps you have never seen a pair of the kind of shears that I am speaking of, and if so this is a good time to become acquainted with one. It consists of a pair of jaws, one of which stands still while the other opens and shuts just like a pair of scissors, cutting off the iron seemingly as easy as you can cut paper ; but of course it takes a very great deal of power to work it. This particular machine is made to cut up the rails for railroads, as you see in the small sketch. In other shearing-machines one shear, or jaw, works straight up and down, while in yet others one side of the machine does the shearing while the other punches holes, which is very convenient for the boiler-maker, as he has so much shearing and punching to do.



A PAIR OF ROTARY SHEARS.

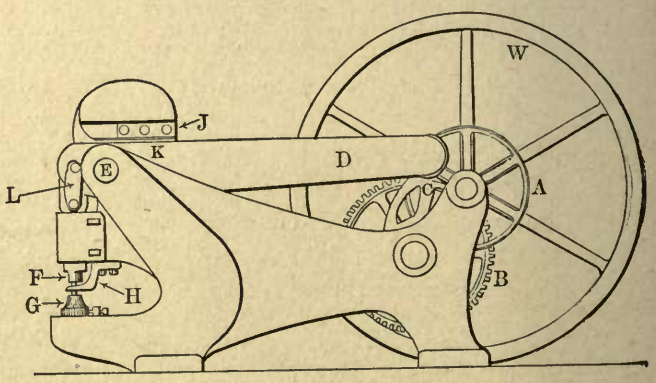
But there is yet another kind of shearing-machine, in which two revolving wheels do the cutting, the plate being simply passed between them. This is called the "rotary shears," and is not suitable for cutting very

thick pieces. Some of the largest shears have their own little steam-engine to drive them, and will cut large pieces just as easily as a small machine will cut small ones, for it is only a question of making the machine strong enough and we can cut any thickness either of iron or steel.



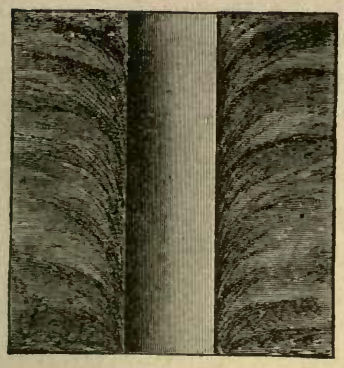
PUNCHING-BEAR.

We were speaking of punching a few moments ago, and I can tell you that there are some very peculiar and interesting facts connected with the simple punching of a hole even in a boiler plate. But it will be best, perhaps, to begin at the beginning and show you some of the means of punching holes. First, then, we have the punching-bear: A is the body, with a slit or jaw at B, through which is a hole for the punch to pass down into. C is a screw with a hole at D to put a lever into to wind the screw, at the end of which is the punch E. The workman winds the punch up out of the way, puts the "bear" on the plate, and then winds down the screw with a lever, and the punch goes through the plate, pushing out a little plug which, when I was a boy, we used to play with and call "dumps." Punching by hand in this way is hard as well as slow work, and so we have the punching-machine, or more commonly the punching and shearing machine. It is driven by a belt or strap on the wheel, A, whose shaft has a small gear-wheel driving the large one, B. On the same shaft as B is a cam, C, which raises up the arm, D. This arm is pivoted at E, and is connected at L to a ram or plunger, F, in the end of which the punch is fastened. At G is what is called a bolster, or die, having a hole through it to receive the punch. At H is a guard that prevents the work from lifting up on the upward stroke of the punch. At J is a shearing-knife, and at K there is another one fastened on the lever D. For punching the work a plate is laid on the bolster G and underneath H, and as the cam C lifts the arm D, down goes the punch through the plate. W is merely a fly-wheel to keep the machine in steady motion.

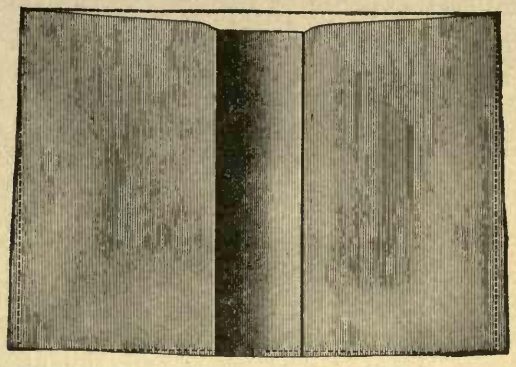


A PUNCHING AND SHEARING MACHINE.

If you place a piece of baker's dough on a piece of board that has a hole in it as large or a trifle larger than your finger, and then placing your finger directly over the hole force it through the dough, it will pierce a hole without pushing any dough out. "What has become of the dough that filled the place now occupied by the hole?" you may ask; well, it has moved or flowed out sideways, and strange as it may seem to you, this same action takes place in punching thick iron, as the little "dumps," of which we were speaking just now, will prove, because the dump will not fill the hole that it came out of, nor will it weigh as much as the

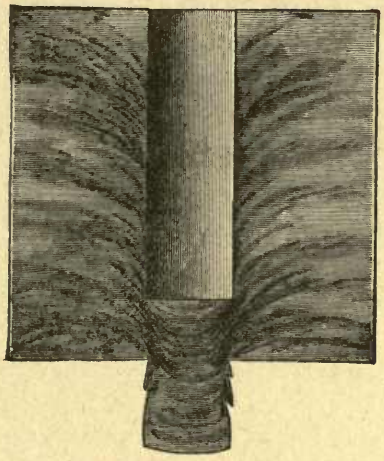


A PUNCHED HOLE.

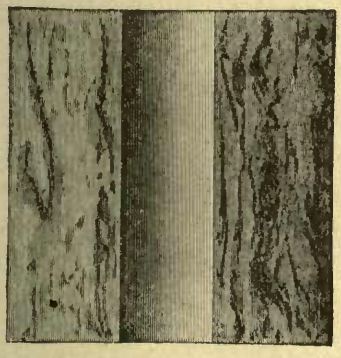


THE WAY THE BLOCK OF IRON ALTERS ITS SHAPE FROM BEING PUNCHED.

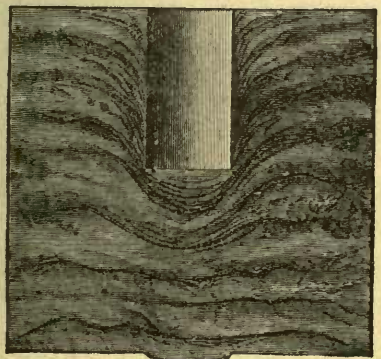
THE "DUMP" THAT CAME OUT OF THE PUNCHED HOLE.



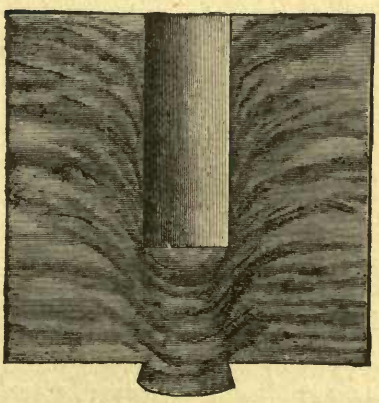
A HOLE PUNCHED ACROSS THE GRAIN.



A HOLE PUNCHED WITH THE GRAIN.



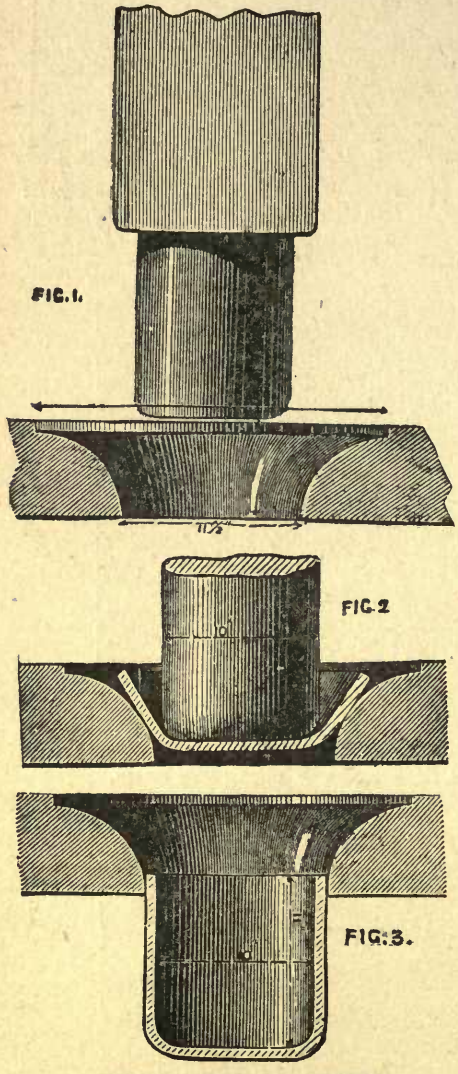
A HOLE PUNCHED HALF-WAY THROUGH.



A HOLE PUNCHED THREE QUARTERS THROUGH.

THE FLOW OF IRON WHILE BEING PUNCHED.

cuttings would weigh if we had drilled the hole. Here, for example, is a square block of iron that has had a hole punched through it, and beneath it is the "dump," or punching, that was pushed out by the punch, and you see that the punching is not more than one third as long as the hole is deep. Clearly, then, the iron has moved or flowed out sideways, although the punching was done cold. Before the iron was punched its uppermost surface was flat, as indicated by the dotted line, but after punching it is cupped, and this iron also must have flowed out sideways, and this is why the iron has bulged out sideways from the dotted vertical lines to the full ones. In order to find out in what direction the iron moved during the punching, the piece after being cut in halves may have its face covered with acid, which will eat out the soft parts of the iron, causing the surface to present curved streaks which show how it flowed during the punching. This piece of iron was punched across the grain, and the darker curved lines show where the pieces or plates of iron joined when they were welded together to make the bar. Next we have a piece that was punched lengthways of the grain, and here you observe that the curved lines do not appear, but the dark lines, instead of being straight, as they were before the punching, are warped from their having moved sideways as the punch descended. A more striking example of the flow of the iron is given when the punch is pressed only partly through, for as you see it goes down a good way before the "dump" begins to form to any extent, and that it forms most rapidly when the punch has pierced more than half way through and towards the last part of the punching operation.

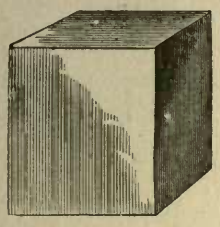


PRESSING METAL INTO SHAPE.

It would seem that the moving, or flowing, of the iron would weaken it, but from experiments that have been made it appears that under some circumstances it actually strengthens it. I ought to tell you though that how much the iron will flow depends to a great extent, and almost wholly, upon what size the hole in the "bolster" is, and that the larger this hole is the less the flow.

Of course it is only the malleable metals, such as steel, iron, copper, and gold, that flow in this manner, and you would readily understand that cast-iron would not. Suppose, now, we take a round, or disc-shaped, piece of sheet steel, and we may press it into a cup shape, and if you think for a moment you cannot help but wonder how the particles of metal must have moved and changed their positions while the plate passed from one shape into the other.

In one experiment that was made a disc of cold steel, 27 inches in diameter and $\frac{3}{4}$ inch thick, was laid over a trumpet-shaped die, and a plunger was forced down on it, pressing it partly down into the die. But as this pressing had made the steel somewhat brittle it had to be taken to a furnace, made red-hot, and then let cool slowly. This is called annealing, or softening, its effect being to make the steel stretch more without splitting or cracking. When cold it was put into the die again and the ram or plunger pressed it further down and

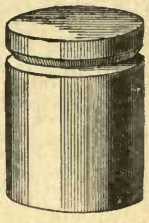


THE PIECE CUT FROM THE BAR OF STEEL.

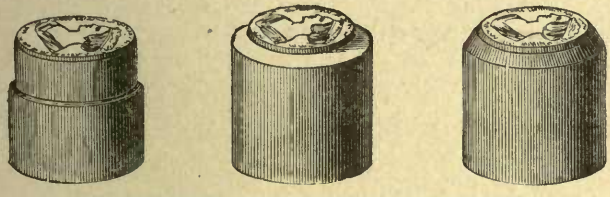
THE PIECE ROUGHLY FORGED INTO SHAPE.

A DIE TURNED TO SHAPE.

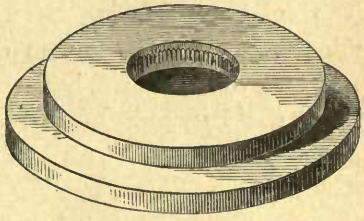
THE PUNCHEON WHEN FIRST IMPRESSED.



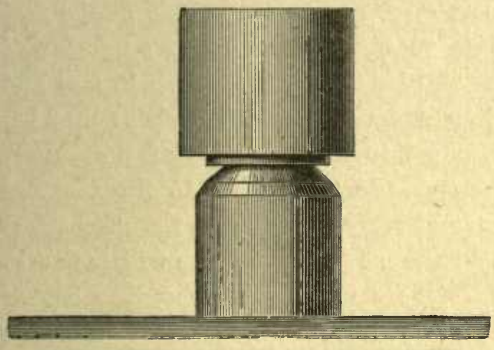
A MATRIX READY FOR THE DIE-SINKER.



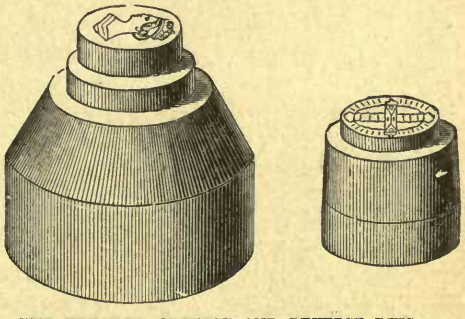
THE DIES WHEN THE IMPRESSION IS COMPLETED.



THE DIE FOR MILLING THE EDGES.



THE PUNCHEON AND THE DIE PUT TOGETHER.



THE FINISHED OBVERSE AND REVERSE DIES.

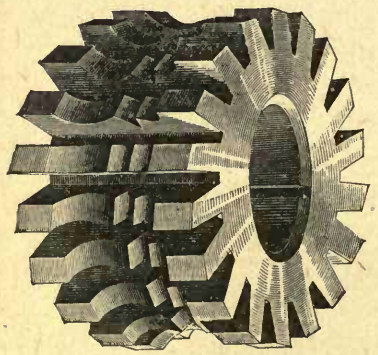
MAKING THE DIES WITH WHICH COINED MONEY IS STAMPED.

into the shape you see, the diameter being 11 inches. The copper shells for rifle cartridges are made in a similar way; but one is not so much surprised at copper bending this way without wrinkling as that steel should do so, even though it is a very soft kind of steel.

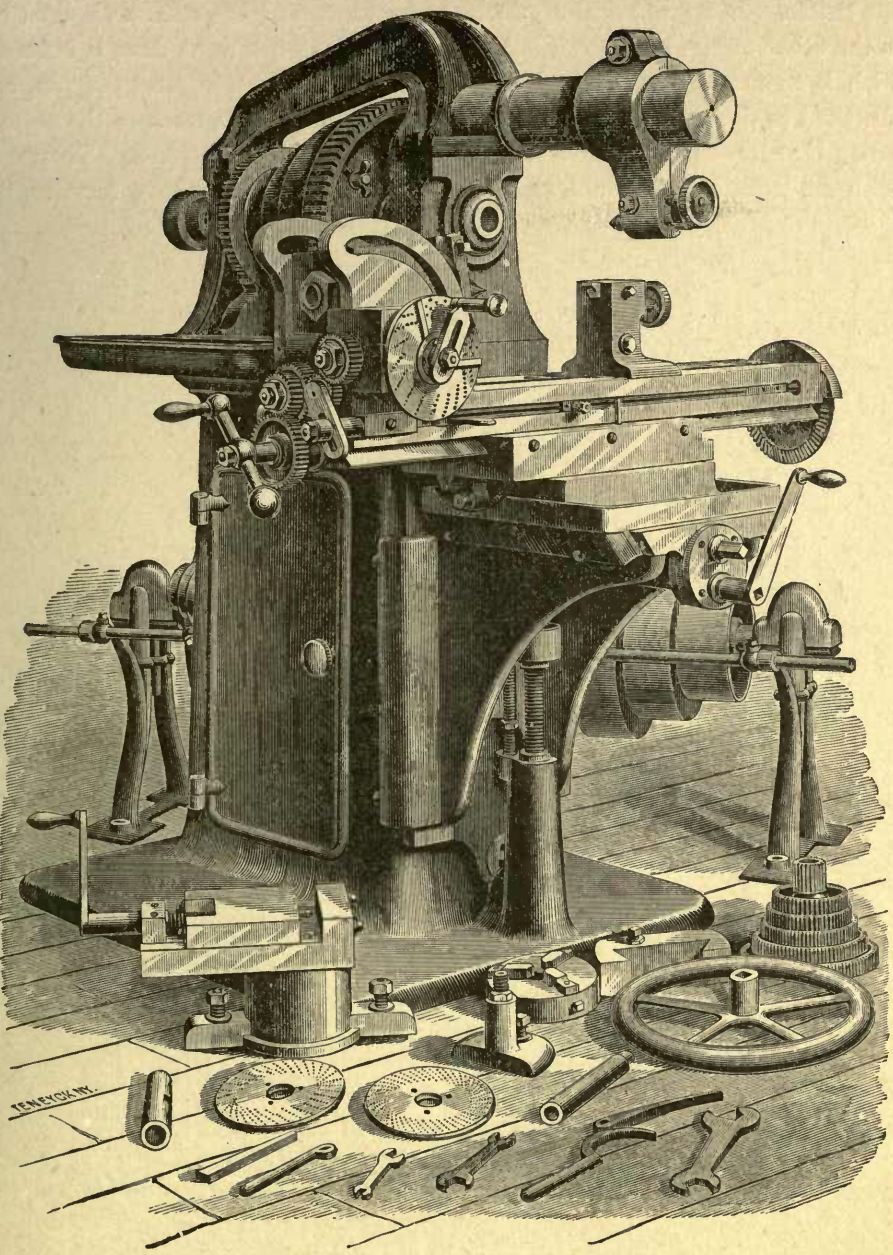
You will get an excellent idea of how cold and fine-grained steel may be pressed into shape from hearing how the dies are made which are used to stamp the figuring and lettering on money. For these dies the very finest of steel is used, and they are at first

simply blocks cut off a square bar. From these square blocks what are called matrixes, puncheons, and dies are made. The matrix and puncheon are simply master-dies from which the actual working-dies are made. These working-dies are called the "obverse" and "reverse" dies, each being suitable for one side or face of the coin or piece of money. Suppose we start from the simple block of square steel just as it is cut from the bar, and the first operation is to forge it into a round shape. It is then annealed, or softened, to make it cut easy, and turned up to make either a "puncheon" or a "matrix," as the case may be. For a puncheon it is turned conical at the top, while for a matrix it is turned flat on the top. The matrix then goes to the engraver and has the pattern cut in it. The numeral figures are stamped in with stamps, and when it is finished it is hardened and fastened in the end of the screw of a screw-press, and a puncheon is placed beneath it, receiving an impression which flattens its point. As this impression has condensed and hardened the steel, it is annealed and then again put on the press to have the impression completed, and then the puncheon is hardened. This puncheon is put on the end of the press-screw and used as a die to make a new matrix, or usually two or three new ones—as many impressions being given to each as may be found necessary to fully develop it. The coining-press, in which the finished dies are used, makes about sixty strokes a minute, impressing the coin on both sides and milling its edge at one stroke.

One of the most interesting metal-cutting tools we have is the milling-machine. I never could understand just why it has been given such a name, nor why the cutters it drives to do the work with should be so often called "mills." The action of the machine is to revolve a cutter, and to move the work beneath it; but you would be astounded at the great variety of work and what different shapes of work can be done in this way. The great usefulness of the machine consists in the fact that when once it is set it will turn out any number of pieces of work that will be exactly alike both in size and shape, no matter how odd or intricate the shape may be, because the work is cut to fit the shape of the cutter, whose teeth have previously been made to the required form. There is something very pleasing to the mechanical eye in a well-formed milling cutter, as you will notice in the one here shown. It would be quite a hopeless task to attempt to show you what a variety of shapes may be made by a very few cutters if the work is moved about under them at different angles and in different ways. For example, the flutes in twist-drills and those in the taps for cutting threads are cut in these machines, as are also the teeth of gear-wheels. Flat work is cut with flat-faced cutters, or sometimes the machine drives two cutters, and the work is passed between them; and on some work one man or boy can attend to several machines, as all he has to do is to put the work in and take it out, for the machine does all the rest itself, moving the work to the cutters and turning it around at the same time if it is required. We do not know who first invented the milling-machine, but we do know that its development to its present state of perfection has been made in the United States, and to a very large extent in the rifle-making and sewing-



A MILLING-MACHINE CUTTER.

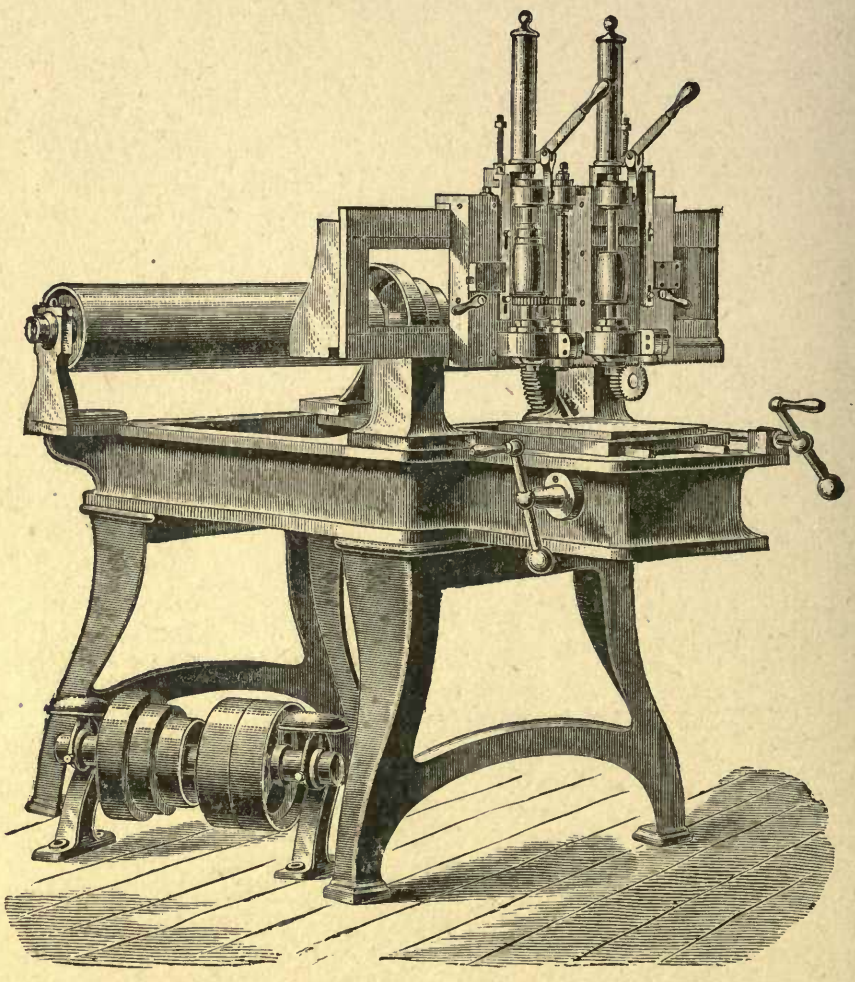


A MILLING-MACHINE.

machine manufactories, where long rows of them may be seen stretching down the shops, all silently cutting away at the iron and steel as easily as you please.

Side by side with the milling-machine we often find the "profiling-machine," which also uses revolving cutters, but holds them in a vertical instead of a horizontal position. There are two vertical shafts, or spindles, which hold and drive the cutters, which are fitted into their lower ends. The work is held on the table, which is moved about and brought

against the cutter. In a great deal of work, however, one of the spindles is used to carry a pin while the other carries the cutter. A pattern of the work to be done is fastened on the table, which is so moved that the edge of the pattern is kept against the pin, and as the work is fastened to the same table the cutter cuts the edge of the work to the same shape as the pattern. Or suppose we want to cut, in a piece of iron, the letter S. Then we make a pattern with the letter S cut or sunk in it, and the pin fits in the groove forming the letter,

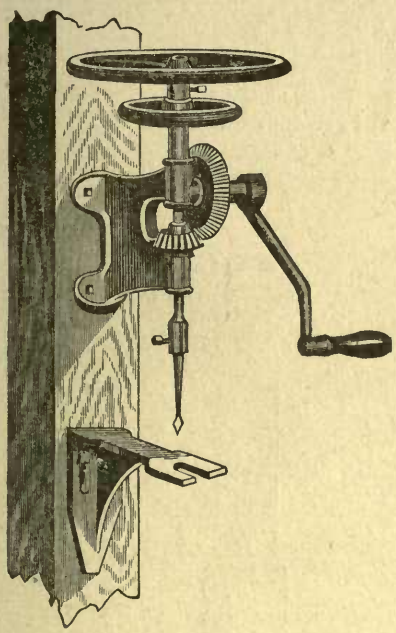


THE PROFILING-MACHINE.

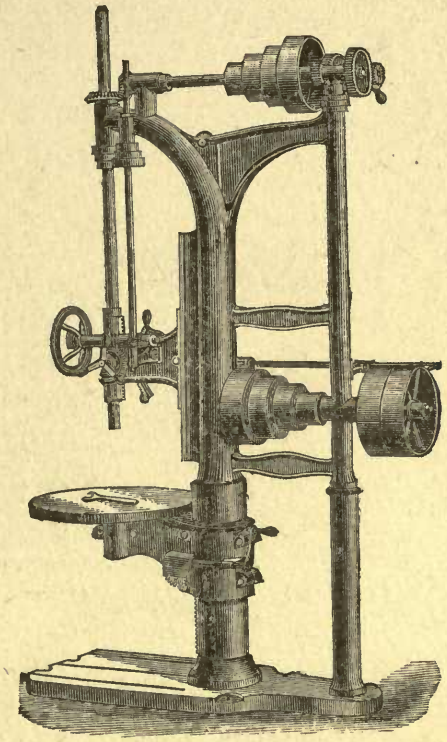
and causes the table to move in the manner necessary to enable the cutter to also form an S. The pin, you must know, is simply a guide that, by fitting into the pattern, enables the workman to wind the handles so as to move the table properly. The "profiling-machine" is a valuable tool, or "machine-tool" (as machines that operate cutting-tools are called), but not so useful as the milling-machine, not only because of its more limited range of work, but also because it has no automatic feed motions.

As we wander through the workshops of this wonderland of work of ours, we pause now and then to think about the number of different methods, tools, and machines there are for accomplishing one kind of work only. Every particular tool or method has some especial advantage for its purpose and each is of interest.

The nature of the material, the degree of exactness of the work, the size of the work, and a great many other considerations, step in to alter the way man attaches it. Just as the difficulties increase so does man increase his efforts. It may take him longer, it may give him more laborious work, but he *will* accomplish it in the end. Look, for example, at what a number of methods there are for boring a hole, and how many different kinds of tools and



BLACKSMITH'S DRILLING-MACHINE.



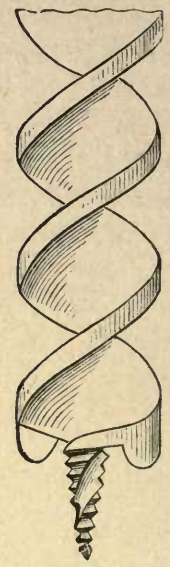
POWER-DRILLING MACHINE.

machines there are for doing it with. First we will take the wood-worker's auger, because it is one of the simplest, one of the easiest to use and the quickest cutting, and we shall find that it alone is made in a great many shapes.

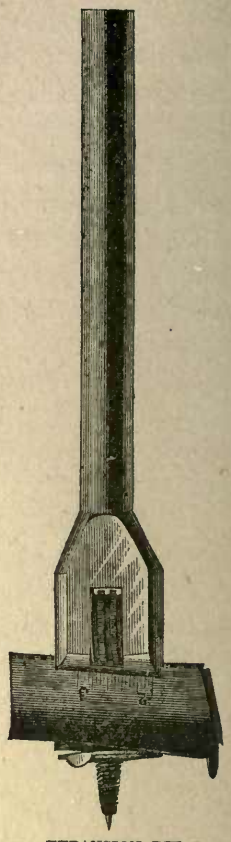
When we want to bore an ordinary hole that does not require to be very straight, parallel, or smooth, we take an auger that is thin at the top of the twist, because it works easy. When we want a straight, smooth hole, we take the dowell auger, because the top of its twist is flattened and so fits the hole closer and keeps it straight. When we want to be sure that the screw at the point shall not clog up, we put a groove in it, and when we want to bore a hole flat and solid at the end we use an auger with no screw and no side wing on it. There are a dozen or two other kinds, however, some of which are spiral like a coiled spring, which are mostly used by ship carpenters.

THE AUGER.

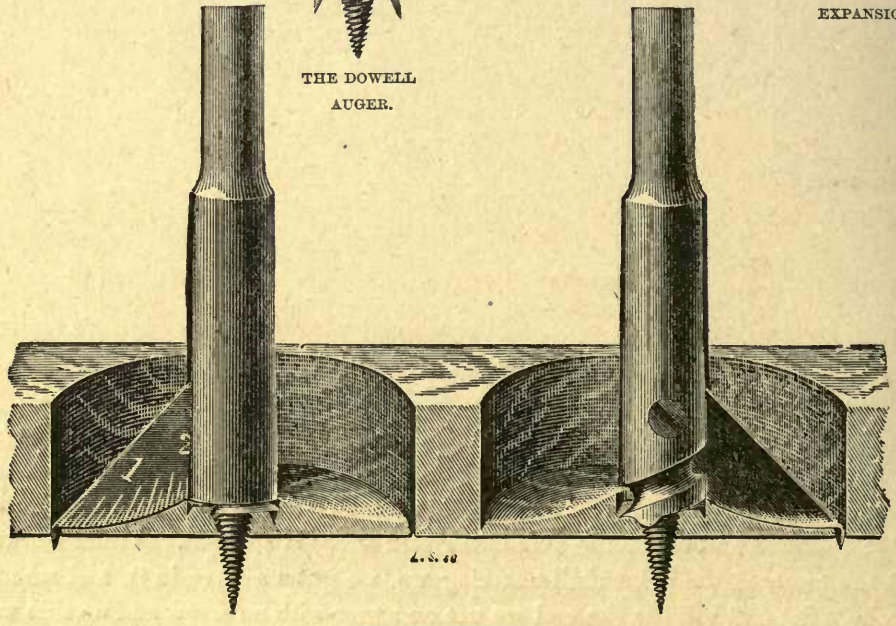
THE DOWELL AUGER.



THE NON-CLOGGING AUGER.

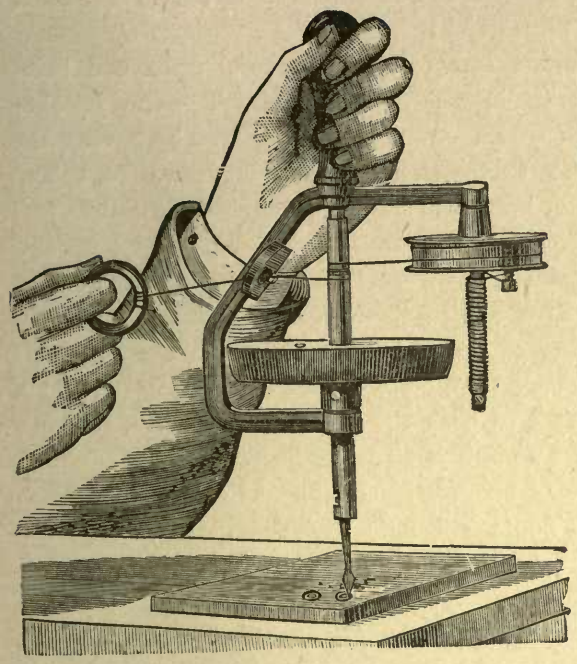


EXPANSION BIT.

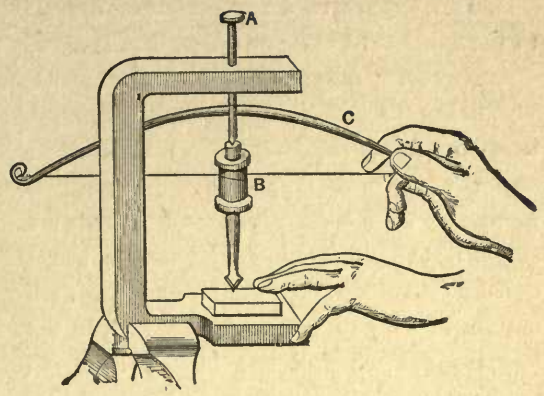


THE EXPANSIVE BIT.

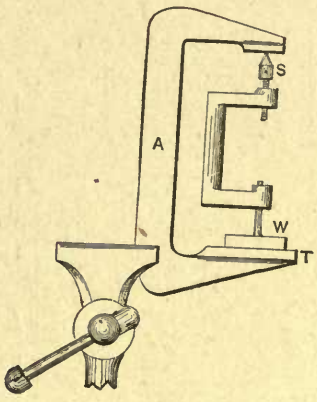
THE WOOD-WORKER'S BORING TOOLS.



A SPRING-REEL DRILL.

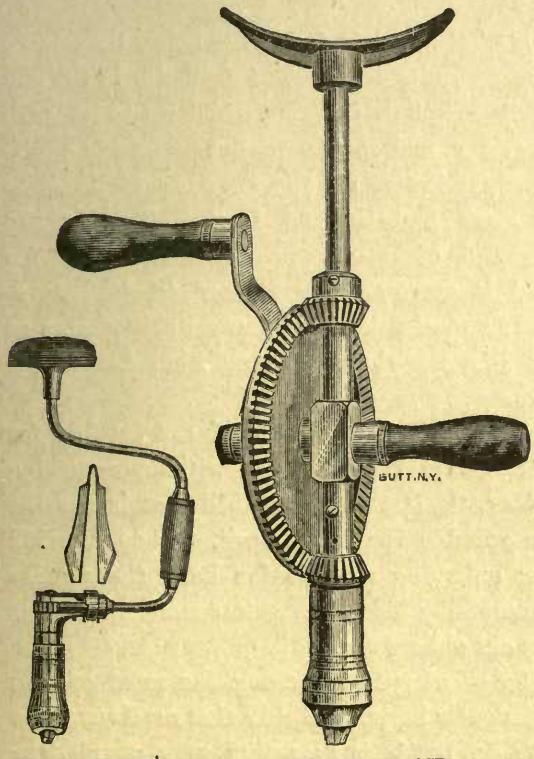


BOW DRILLING.

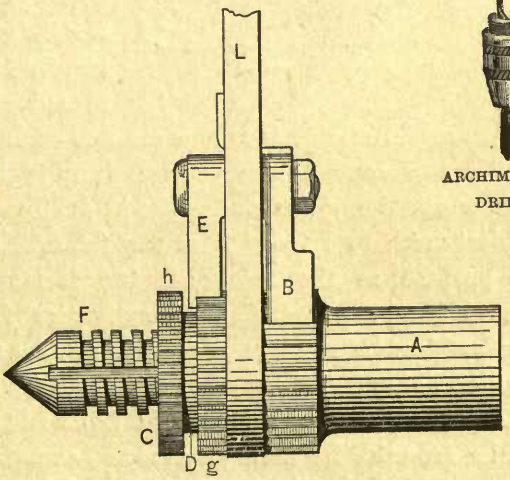


THE DRILL CLAMP.

ARCHIMEDIAN DRILL.



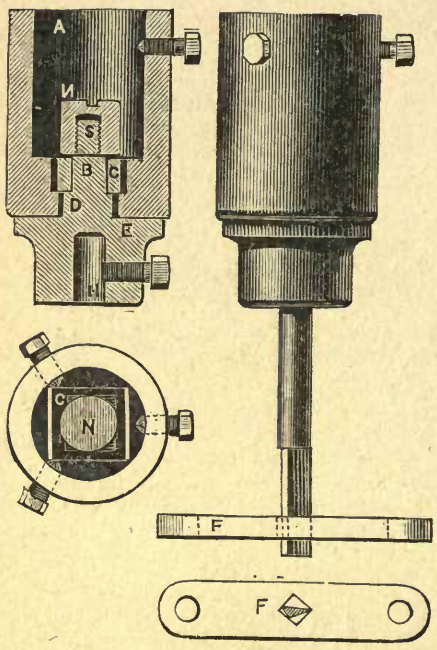
THE CARPENTER'S BRACE. THE DRILL BRACE.



THE RATCHET BRACE.

The expansive bit is one that has a "bit" that can be moved in or out of the stock to bore different sizes of holes, and is a very useful tool indeed.

Next we may glance at the more common forms of iron-workers' drills and hole-producing tools and appliances. First, the fiddle-drill or bow-drill which the jeweller uses so often. It is merely a drill fixed in a reel or spool and revolved by having the string of a bow lapped once around it, so that when the bow is drawn back and forth the drill is revolved and pierces a small hole very easily and readily. Another tool for just the same kind of work is the "archimedian" pull, in which you pull up and down a barrel-shaped ferrule, and the drill stem is revolved because the stem has grooves cut in it, as you see, and the ferrule acts as a nut in these grooves. When we get to larger holes we find the blacksmith's drilling clamp which he fastens in the vise. It has a small table at T to put the work on, and a screw at S to push the drilling brace with, forming in reality a more powerful substitute for the common carpenters' brace. The spring-reel drill is very much like the fiddle-drill, only that you pull a cord instead of the bow, and a spring pulls the reel and drill back again.



DRILLING SQUARE HOLES.

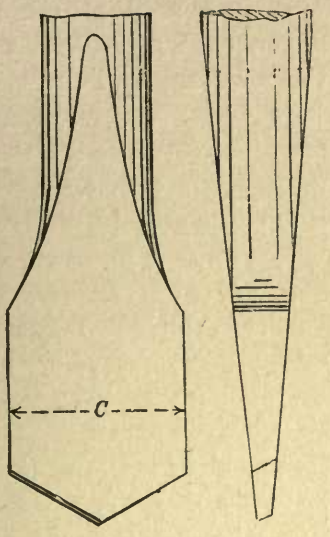
The iron-workers' breast-drill has, as you see, gear-wheels to it, so that the drill may make several revolutions to one of the handle by which the operator turns it.

The ratchet brace is for larger holes, the handle L being made quite long. The drill fits in the end of the body A, and is fed or pushed up to its work by the screw F, and as this particular one is a self-feeding ratchet brace, all the man has to do is to pull the lever L back and forth. This is the most powerful of man's hand-drilling tools for metal, and is correspondingly slow in its movements, for in mechanics it is generally the same as in animal life, the slower the machine moves the more powerful strains it can cause and endure.

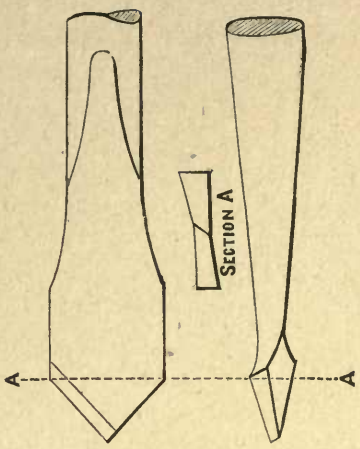
We now come to the common form of iron-workers' drill and find the flat drill for rough work, the quick-cutting twist-drill that always keeps its size without requiring the blacksmith to reforge it as the flat drill does, the straight flute drill that is for the same purpose as the twist-drill, but is more suitable for brass work, the countersink for cutting taper recesses, the counterbore for enlarging a part of a hole, the reamer for smoothing out a hole, the rose-bit also for smoothing holes, the cutter stock and cutter for larger holes, and the slotting drill for cutting out oblong ones.

There are many other kinds of drills and hole-boring tools, among the most curious of which are drills for boring square and even triangular holes, by a drill that revolves while cutting. This looks like an impossible thing to do, but it is in reality very simple, the

STRAIGHT FLUTE DRILL.

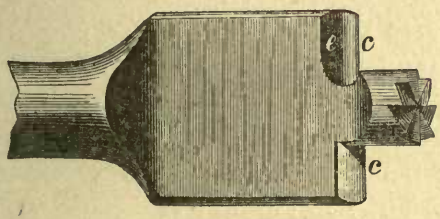


FLAT DRILL.

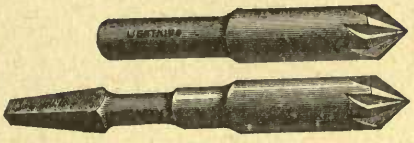


TIPPED DRILL.

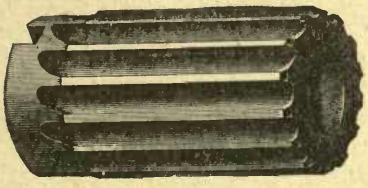
TWIST DRILL.



COUNTERBORE.

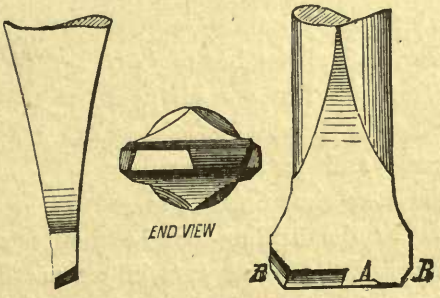


COUNTER-SINK.

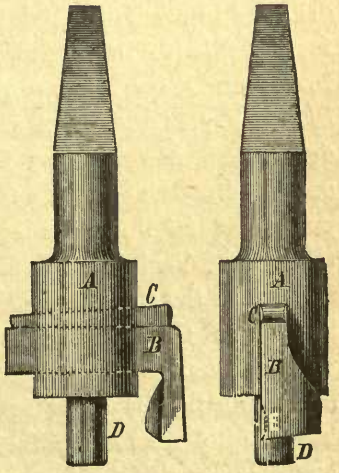


REAMER.

ROSE-BIT.

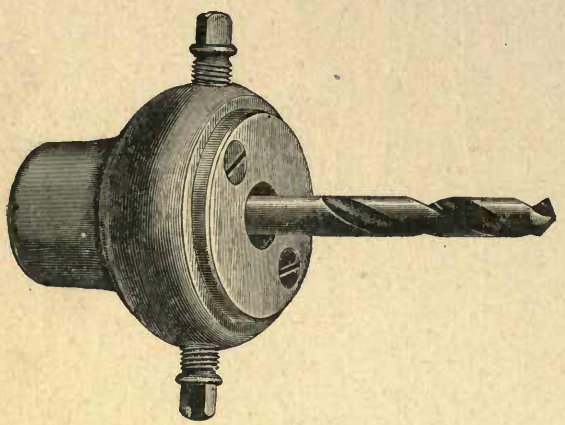


KEYWAY DRILL.



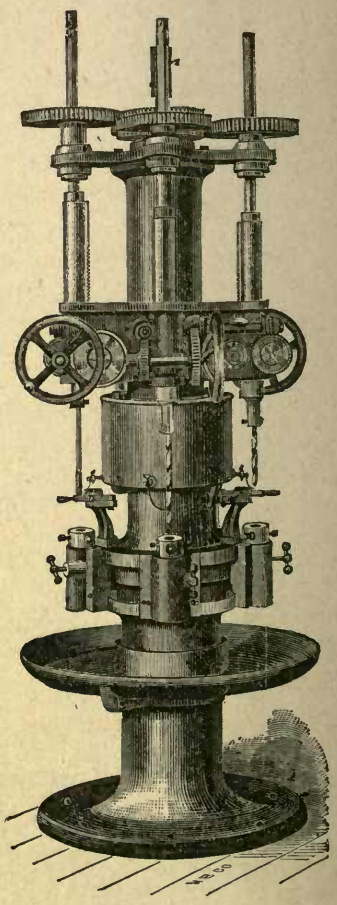
CUTTERS.

whole secret being in letting the drill pass, before it reaches the work, through a fixed guiding plate that has in it the shape of hole you want to drill, and then giving to the revolving drill liberty to move sideways while it revolves, so that it can move about and follow the shape of hole in the guiding plate. The letters A, B, C, etc., are on the parts that drive the drill and permit it to move sideways, and F is a guiding plate for drilling a square hole.

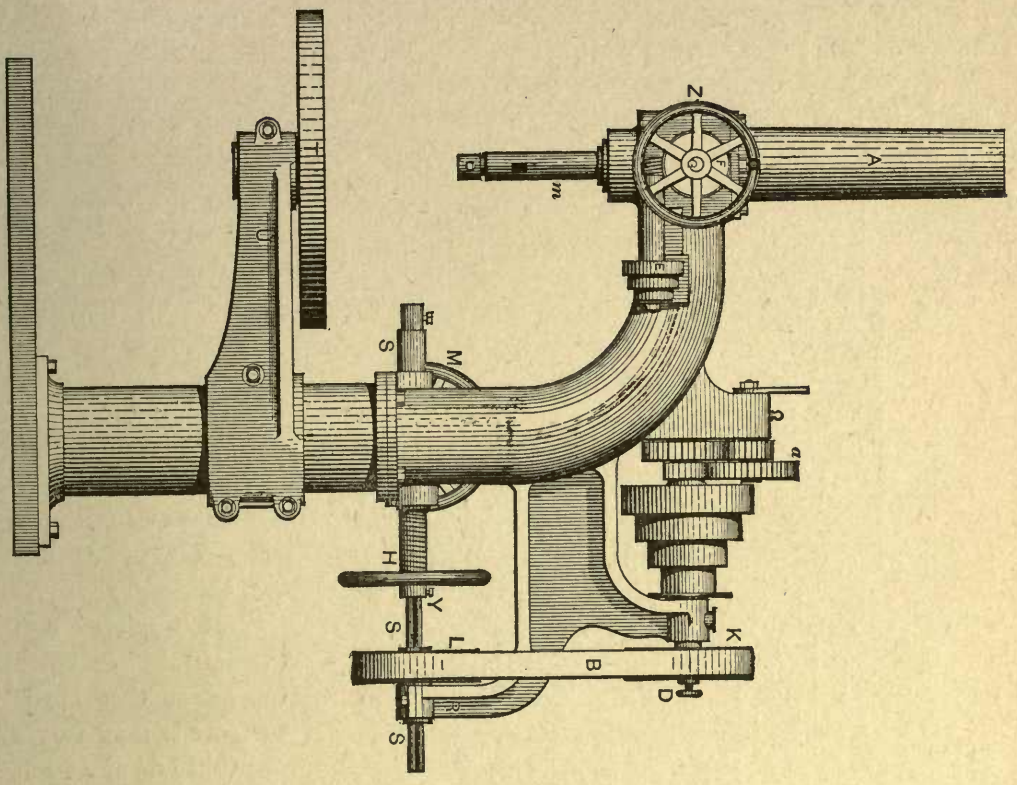


A DRILL-CHUCK.

The drilling-machines for driving hole-boring tools assume as many shapes as the different drills themselves do. The machines for boring holes in wood run very fast, because wood is easy to cut; those for iron drilling run slower in proportion, as the hole to be drilled is larger in diameter, the depth of the hole making no difference to the speed of the drill. Sometimes one machine drives several drills, and is called a multiple drilling-machine, or a *two*, three or four spindle drilling-machine, the spindle being the shaft to the end of which the drill is attached. Sometimes the end of the drill fits directly into the end of the spindle, and at others it is held in a chuck that fastens to the spindle. The blacksmith's hand-drilling machine is often bolted against a post and the drill is worked by hand. In the power-drilling machine it is worked by a belt, and there are mechanisms consisting of gear-wheels, etc., to regulate the speed of the drill and to move or feed it to its cut. Here is an automatic four-spindle drilling-machine, there being beneath the drills four sockets for holding the work. These sockets are held in a table that can be revolved so that by moving it one-quarter of a revolution the work is moved from beneath one drill to the next one, so that four operations can be performed on the work by one man, and all he has to do is to set the drills in the spindles, and then stand at one of them and put in the work and drill it with that one spindle. Then he moves the table one-quarter turn and puts in another piece of work and operates on it the same time that the piece he put in first is being operated on by the drilling-tool in the second spindle. Then he moves the table another quarter revolution, and puts in yet another piece of work, and so on until the first piece he puts in comes back to him, when he takes it out

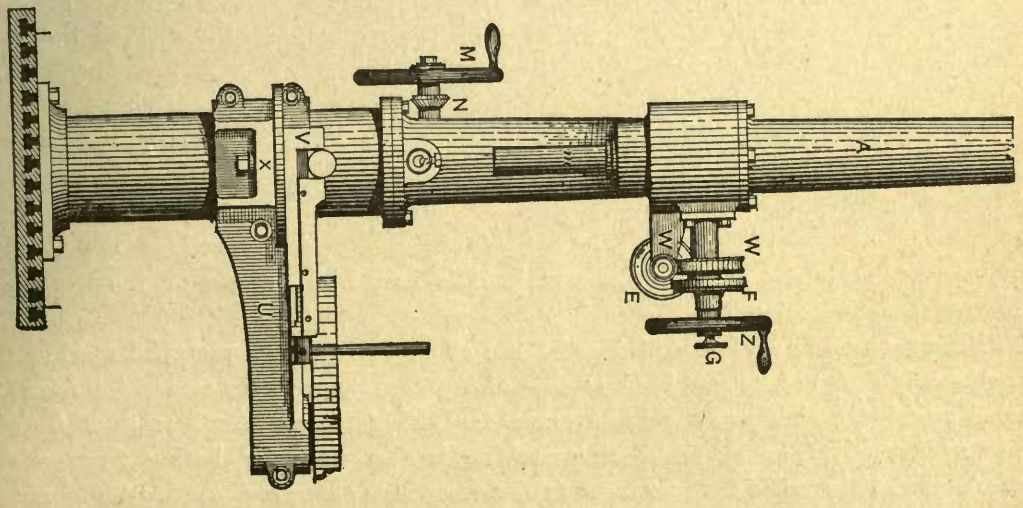


A FOUR-SPINDLE DRILL.



SIDE VIEW.

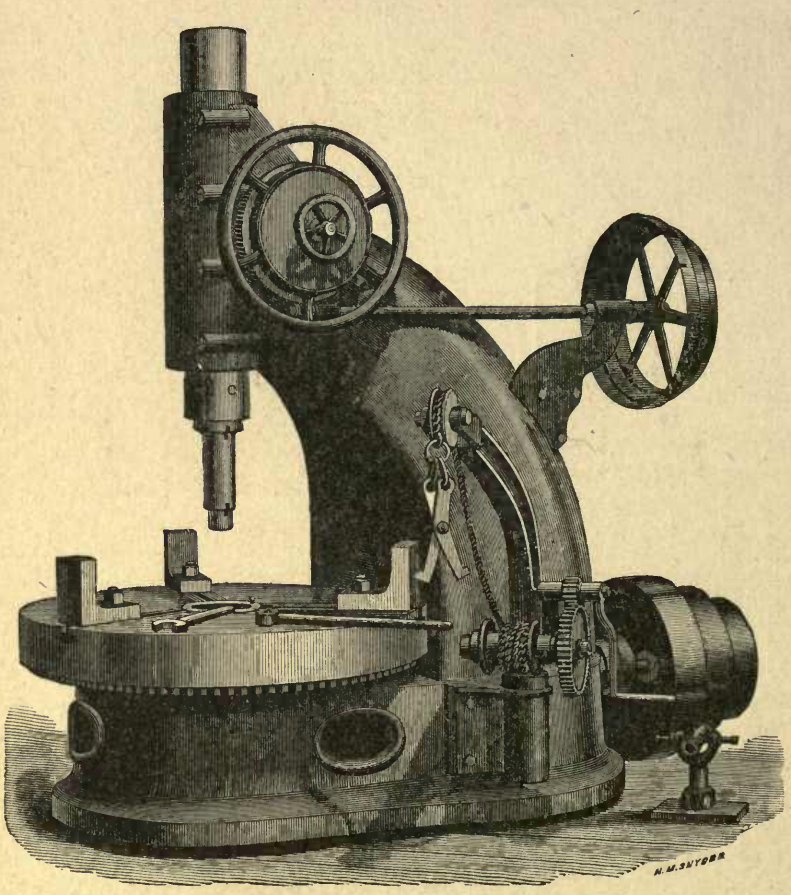
DRILLING AND BORING MACHINE.



FRONT VIEW.

and puts in another one, and so on, thus doing four pieces of drilling at one time. Beside the drills you see spouts which supply them with oil, to make them cut easy and preserve their cutting edges, and below the revolving table you see a dished pan to catch the cuttings and the waste oil, which is drained off and used over and over again.

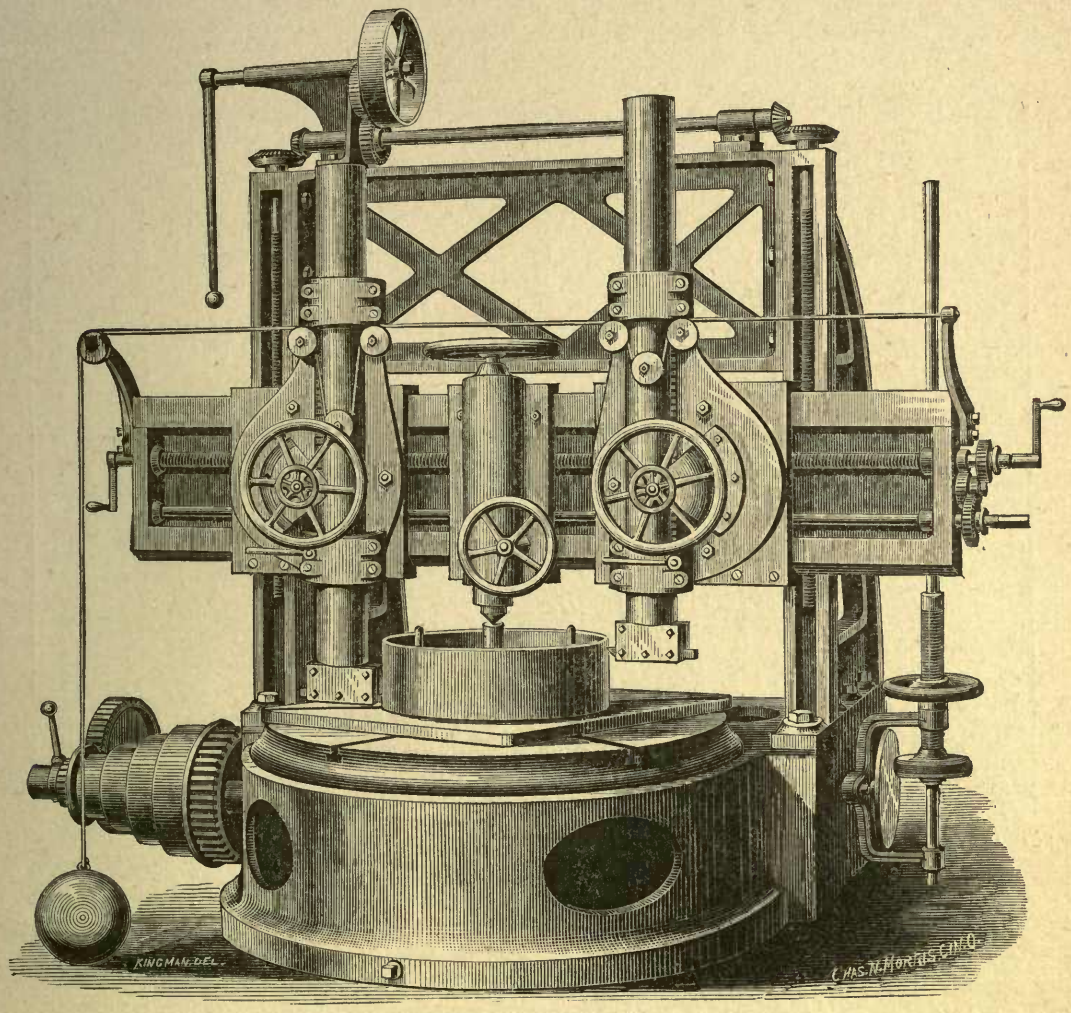
The wood-worker does not use the word drilling, but always calls the operation boring, while the iron-worker calls it drilling when he cuts the hole out of the solid, and boring when he simply enlarges an existing hole. In the one case he uses a drill, in the other a boring-tool or a boring-bar. But the iron-worker sometimes uses the same machine to both drill and bore, making it powerful enough to bore as well as drill. Boring-machines always have self-feeding mechanism, while drilling-machines for small holes often have a "hand feed" only, which means that hand pressure is used to push the drill into the work. To hold the work firmly it is bolted to the table T, and the drill or the boring-bar goes into the end of the spindle M. The wheels at *a* are for driving the machine, and the belt B is for driving the spindle S, so you see that this machine has two spindles, one being vertical and one horizontal, while both may operate on the work on the table T at the same time.



THE CAR-WHEEL BORING-MACHINE.

Boring operations often call for the use of very large and powerful machines, and are generally designed for one kind or class of work only, as in the case of the railway-car boring-machine, which you see has a crane for lifting the car wheels on or off the work-table or chuck. The largest boring-machine is that used for boring fly-wheels for steam-engines, in which there are two boring-bars, carrying cutting-tools at their lower ends, one of which may be used to bore the hole and the other to turn up the

outside of the pulley, or both may be set to operate on the outside of the work as you see in the engraving, in which a pulley is shown on the work-table. Now although this machine can do turning as well as boring, it belongs more to the boring than it does to the turning-machine family, but, strange to say, is called a "boring and turning mill." Its boring bars may be set at any required distance apart, and at any point across the table, and may be moved either horizontally or vertically either by hand or by self-acting



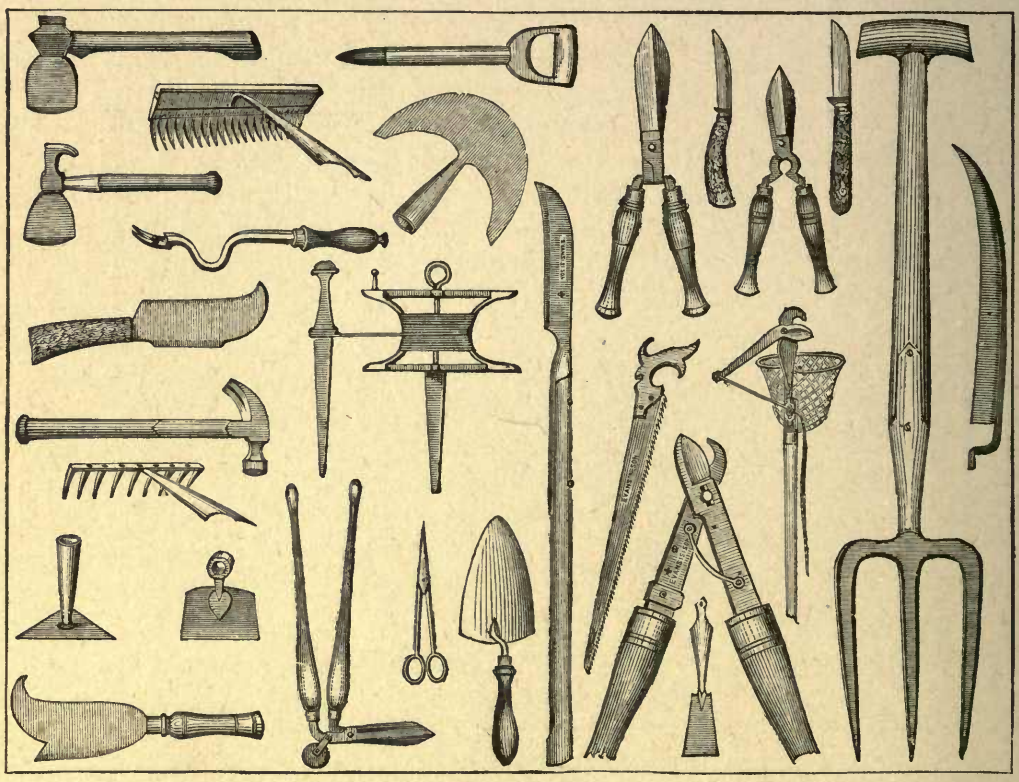
A BORING AND TURNING MILL.

mechanism, so that it is a very ingenious machine. It was invented in England, but has been improved and is more universally used in the United States.

Many "heavy steel tools" are formed both of iron and steel, being partly forged and plated under the broad face of a tilt-hammer, after having been prepared or "moulded" by hand-forging. Thus that part of a wrench likely to be subjected to great tension would be of iron, the remainder fashioned of hard, fine steel. As we turn from one to another of these countless useful things which our workers have extracted from shapeless

lumps of ironstone, and have forged, rolled, squeezed, drawn, moulded, cast, or cut into shape, we are reminded of what our wise and thoughtful Carlyle wrote on this very subject:—

"Man is a tool-using animal, weak in himself, and of small stature; he stands on a basis of at most, for the flattest soled, of some half square foot insecurely enough; has to straddle out his legs, lest the very winds supplant him. Feeblest of bipeds! three quintals are a crushing load for him; the steer of the meadow tosses him aloft like a waste rag. Nevertheless, he can use tools, can devise tools; with these the granite



SHEFFIELD TOOLS.

mountains melt into dust. Before him he kneads glowing iron as if it were soft paste. Seas are his smooth highways, winds and fire his unwearing steeds. Nowhere do you find him without tools. Without tools he is nothing—with tools he is all."

As children there was nothing we liked better to watch than the blacksmith at work in the village smithy. Wonderful seemed the strength and dexterity with which he wielded the hammer over the various bits of whity-red metal, which spattered angry sparks in every direction, as though protesting against the heavy blows which were bending it about like dough to suit any required purpose. Now, though the smith still hammers bits of iron into shoes, it is not at the same rate, for machinery (American mostly) has taken up the greater part of his work, and turns out unlimited numbers of horse or ass shoes, just as it also turns out metal "heels" and "tips" for any

number of strong boots which sturdy boys may kick out; but his task is easier, as the blacksmith of to-day is provided with a good supply of iron bars of all sizes, shapes, and lengths, so that whatever sort of job he has to do the material is ready at hand in a convenient form, and, being heated, is soon bent and beaten into shape, for this rod iron lends itself to any kind of work, and saves him much time and trouble. A great quantity of it comes from the foundries of South Staffordshire, and serves innumerable purposes. Besides being fashioned, as we have seen, in the village smithies, it is employed in large works, where machinery turns it into many familiar and useful forms (from park railings to pokers), besides snipping it into endless nails of all sorts and sizes, bolts, bars, and fire-irons, garden gates and railings. It is twisted into chains and cables at the rate of some 60,000 tons annually—enough, one would naturally fancy, to wind round the world.

The iron rods intended to be used for this purpose are all cut into short lengths by means of strong shears that snip up the cold, hard metal bar as though it were a sugar stick. If these lengths are intended to form a big cable, they may be made red-hot in a furnace, and placed in a "bending" machine which twists and curves them into the required link-shape; but they, as well as every other kind of iron chain, must, to be depended upon, be forged by hand and hammer; no machinery can supply the effect of the intelligently repeated "bang" which can alone insure solidity of weld, the all-important consideration in these useful articles, many of which are made at the "shops," though many little smithies in the neighbourhood of Birmingham still ring with the clang of hammers forging and forming innumerable links that may one day help to keep our ships fast, or even act as a neat but sure restraint to check Pompey's wandering inclinations. The chain-forger and his family, like the poor nail-makers, work hard for little pay, and are like them very rough-and-ready people, not particularly fond of being watched at their task; yet it is curious to notice with what dexterity they make link after link of metal, working with two long rods, one heating in the forge fire, while the red end of the other is being snipped off, crooked, linked through another link, bent, and welded together so neatly that the join is not to be distinguished, and all this done somehow in a twinkling or less, just the time the last bar has taken to get hot again, and ready for the skilled hand stretched out for it.

I do not know where we can find a better place in which to learn something of the useful nails and screws which must be employed in the different departments of the busy furniture manufactories. What an endless supply there seems to be—drawers fitted with nails of all sorts and sizes, from the tiny neat tin "tacks" a quarter of an inch in length to the mighty "mop;" from ordinary "clasps," much used in builders' woodwork because they sink rapidly and easily down into the surface of the wood in which they are driven, and which can therefore be neatly planed and smoothed over them, to the round-headed clout nails which are employed to secure metal and wood together. We can only sum them up by stating that there are three distinct kind of nails manufactured in this country—wrought nails, cast nails, and cut or "punched" nails—but of these three kinds I am informed there are three hundred varieties, each variety averaging ten sizes, one or the other of these serving every possible purpose.

I once read of a tribe of African savages that, on being presented with a bagful of nails by some European traders, proceeded at once to sow them carefully in the earth, taking them for some sort of rare seeds, and expecting that, as a matter of course, they would produce a fine crop of their own kind. But nails are not quite so easily obtained, though the roughest and simplest sorts are turned out at an astonishingly rapid rate.

"Wrought" nails are made by hand on a small steel anvil, and of a special kind of iron called nail-rod, made by rolling the metal into plates of the requisite thickness, and cutting them into long thin strips in what is called a "slitting" mill. Some years ago there was no other kind known, and 50,000 men, women, and children earned their living by this business; but now machinery has taken it up, and nailers are getting fewer every day, though still, if we wander about the neighbourhood of Birmingham, or through the hamlets about Dudley and Bromsgrove, dingy, dirty Smethwick, for instance, the very heart of the nailing district, we shall see bright forges burning in the depths of the smoky cottage rooms, or in little sheds outside—humble forges, at which stand whole rows of stout-armed women brandishing big, heavy hammers as though they were toys; for this hand nail-making has always been a home trade at which father, mother, sons, and daughters, even quite little ones, worked together at a hard task badly paid for by the nail-masters.

These nailers usually worked at different kinds of nails. There were "hundreds," those who only made large nails or spikes, and "thousands," who produced neater work; some turning out horseshoeing nails (this branch of the trade was, however, in the hands of men only), others clasps, others rose, clouts, tacks, brads, and so on. By this means they acquired great perfection and dexterity at their speciality, working so fast that one nailer is known to have made 40,800 "flooring clasps" in two weeks, the wonder of which we shall better understand if we remember that to do this he had to heat a rod of iron 42,836 times, weld together all sorts of short pieces, and strike each nail with his hammer twenty-five times.

If we peep into one of these dingy shops where the nailer, who, as we know, if it be any but a horseshoe forge, is most likely a woman, we shall find her with the sleeves of her old stuff gown pushed very high, hard at work mid grime and smoke, with very likely a mere child toiling at the bellows. There is but little else to be seen, for the place is bare and dismal. There is the small anvil on its low block, chisels, a variety of tools, pieces of perforated steel, and what is termed a "bolster," through which the long spike of the nail is to be dropped that the head may be formed, unless it is an ornamental one, in which case it will be formed by a "swage," or die, or perhaps by an "oliver," or double hammer worked by treadle and cords, one hammer drawing out the shank while the upper end of the nail is held fast in the "bolster" under the other hammer, on the face of which a die or pattern of the nail-head is hollowed. At a touch on the treadle this end of the hammer comes down with a heavy snap on the rough protruding end of the nail, which is thus at a touch driven into the required shape.

But just now this is not what we shall see, for our nailer—or there may be several, as sometimes they hire a hearth, or "standing," when they have not one at home—takes

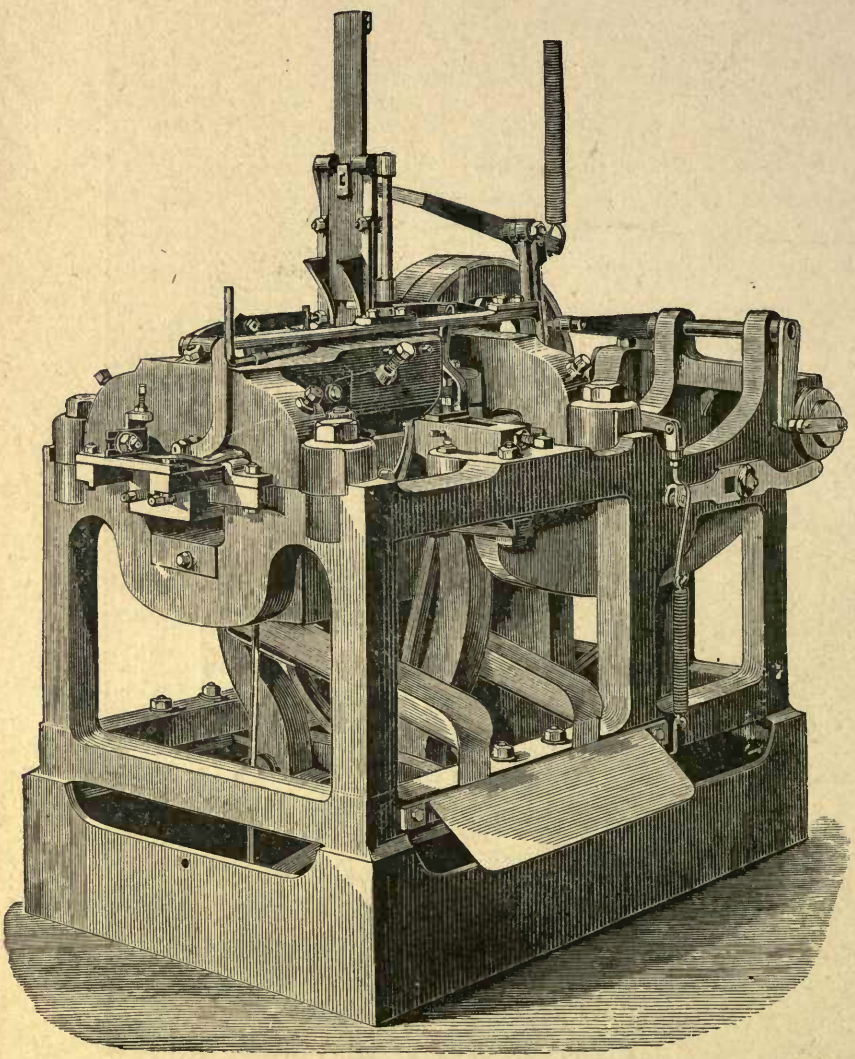
up her big hammer, weighing some twenty pounds or more, and having but one striking face inclining towards the handle; then she places several long thin rods of iron on the

THE NAIL-MAKERS.

hearth fire, which she or the child brightens up by means of those big ragged bellows; then, as fast as one of these grows white-red, she takes it out of the coals, places the hot blunt end on the anvil, hammers it into a spike, snips it on the chisel, then drops the loosened spike end into one of the two holes in the "bolster," cuts it off from the long rod and by

a few well-directed heavy blows turns the rough upper end into a knob, then into a neat head—the whole task being accomplished in less time than I have taken to describe it.

But as we know machine-made, or *cut* nails, as they are termed, are slowly making their way, because they can be made so much cheaper. "Rose," "rose clasp," and "horse" are those in which machinery has as yet succeeded in rivalling hand-work in England. But in the United States the cut nail has driven forged nails completely out of common use, relegating them to a few special uses on fine classes of work, for the hand-forged nail is still the best and strongest, especially for cases in which the end requires to be well clinched over without cracking or breaking.



A NAIL-FORGING MACHINE.

But some of these cut nails, such as clasp, rose, slate, clout, and the large and useful family of tacks, require to be properly headed. To begin with, they are all formed as mere wedge-shaped sprigs, thick all the way through as the sheet of metal out of which they have been cut by the slicer of the nail-making machine, but those intended to be headed drop straight into "grips," from which they project somewhat, until a sliding bar bearing a heading-die suddenly "upsets" the projecting bit, and leaves it shaped into a head, after which the nail is pushed aside to make room for another.

These ingenious nail-cutting and heading machines are self-feeding, often snipping off five strips of metal at one time, and cut and stamp at such a rate that they will turn

out somewhere about a thousand neat and useful sparrables—which ought to be sparrow-bills, being named after their shape—sprigs, or brads, per minute, and the larger and more complete "headed" nails at the rate of from seventy to one hundred in the same time.

Most of the "tacks" thus turned out are somewhat smartened, though principally to prevent their rusting, before being sent on their way through the world, by being tinged blue or black, or even made almost to resemble silver. This is done in various ways. The last bright "white tacks" are first thoroughly cleansed by soaking in a pickle of diluted sulphuric acid, then washed in clean water, wiped, covered with powdered resin, and dipped in a bath of molten tin.

There are other special kinds of nails used in our Wonderland, where such things represent the pins and needles of domestic life. There are the long, fine, straight "pointes des Paris," made from iron wire, which seem mostly to hold very fast those numerous packing-cases and crates for one use and another, made chiefly of soft clean willow-wood, which come to us, filled with eggs or toys, from the Continent. These nails are easy to get in and difficult to get out—great recommendations for their particular purposes. These shining "pointes" are from one to four inches long, and made by machinery which cuts, heads, and points them quite independently of any assistance. There are also a few kinds of brass nails, made of an alloy of copper and tin, used as ornaments, or for the fastening of copper or patent sheeting to the hulls of ships or other places.

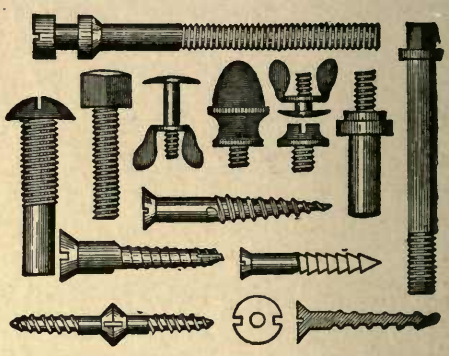
Before leaving this subject, we must mention one of the cheapest and roughest kinds of nail, used to hold laths and plaster together, but more employed in the vinery or garden walls than anywhere else, I think. These are all cast in sand moulds, such as we have seen in a foundry, the impression of a nail being taken in halves, which are clamped together, then the boiling metal being allowed to run in and fill the hollow—a simple enough process; but the cast nails thus produced are too coarse and brittle to be of much service.

And next concerning the several varieties of "wood-screws" used by our carpenters and joiners in many kinds of work where ordinary straight nails could not be relied upon. "Wood-screws" are made of iron wire, and are principally distinguished one from another by the form of their heads. They were made singly by hand, the blanks being forged, the "slip" made by a hand-saw, and the "worm" turned in a lathe, until, little more than a hundred years ago, a complicated apparatus was first invented which aided somewhat in the task, though still it remained a slow and tedious one, until taken in hand by Colbert, a clever German clockmaker, who invented machines for the purpose, the same in principle as those still in use, but of course they have been much modified and improved upon. Now, instead of counting his "wood-screws" by the hundred, the dealer reckons by thousands of dozens, no less than 9,000 tons of iron wire being employed in one year for the making of 9,000,000 gross of these useful little articles.

Unlike wrought nails, screws, which once also formed home-work for entire families, are now made in large factories, which usually possess wonderful automatic machines that first came from America, and the use of which has worked a complete revolution in this special industry, and caused screws to be cheaper and in much more demand.

These machines are certainly wonders of their kind, though I am not sure I can

make you quite understand how they work, or how those great coils of metal wire can ever be changed into these various neat little screws, which serve so many useful purposes. The first thing done is to cut it into "blanks," or plain lengths. All the attendant has to do is to place one end of the coil under a holder, which, taking a firm grip of it, proceeds, all unaided by man, to do what is required; and a very curious "all" it is, for first we see a sort of paw rush at the intruder and eagerly drag it into a round hole cut in two blocks, which close up and hold it between them, leaving a small piece of the wire, which is to form its head, projecting. Then a heavy, sturdy steel bar rushes up full at the projecting piece, squeezing and crushing it into the die which is in the end of the blocks, and thus violently fashioning it with a certain and resistless force there is no avoiding. The blocks then slip sharply aside, which movement cuts off the bit of wire from the long coil, its tail; they then loosen their tight hold, and with a sudden shove the short blank drops into a receptacle below, where it is almost instantly joined by another, and another, and thousands of others, for the untiring machine never stops or wavers until the whole shining coil lies snipped into blanks, and then it is quite ready for a fresh bite at the next one provided.

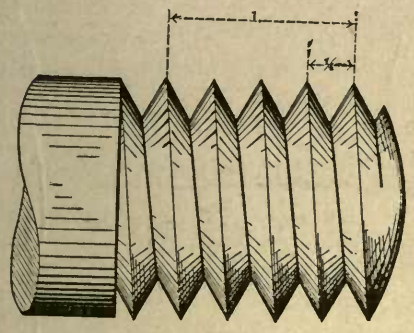


SCREWS FOR VARIOUS PURPOSES.

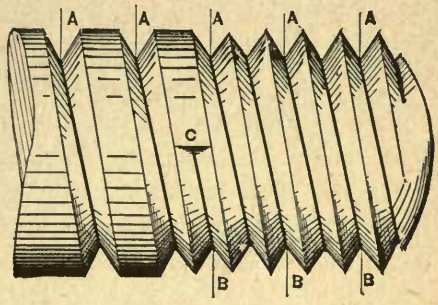
And now for the "turning," that very particular part of a screw, which is done in a larger and very different machine, whose work is even more surprising to an unaccustomed eye, if we can only manage to follow the different parts as they fly in and out. All these as yet rough "blanks" are placed in a receptacle, or hopper, near the top of the machine, where they lie all of a heap. In this hopper there appears to be a four-armed thing very like a metal windmill, which certainly twirls round and scatters that heap of short pieces lying thick about it, one or other of its arms for ever catching a few and sending them flying, first on to a platform, from which they slide on to a slotted incline, into which they tumble and struggle in a bewildered fashion; their numbers are, however, regulated by a contrivance which prevents their being in too great a hurry, so that at last when they arrive at a kind of little door they form quite an orderly procession.

So far all is clear, but now for what happens we must watch closely to note how the little door opens, allows *one* blank to pass through, then what might be two hard iron fingers snatch up the intruder and place it opposite a clamp, which opens to take it, and that it should make no difficulty at entering, a little rod facing the clamp pops out and gives a helping push; then the clamp holds it in a firm grip, while a sharp cutter rushes up from somewhere to work its will on the blank, and then to vanish as suddenly; the clamp loosens its hold, a rod gives a shove out of the way, meaning "make room for a newcomer," and it drops down into a pan, in which it finds many of its brother blanks that, like itself, have had all their heads neatly turned and all their ends ground to a point.

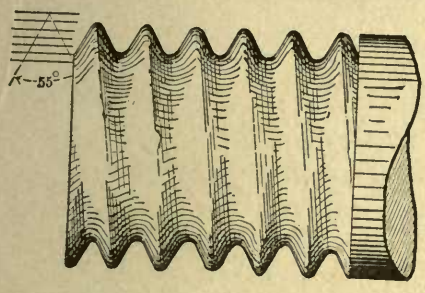
The screws used for holding iron-work together are very different affairs from those used for wood-work, both in their "pitches" and in their shapes. But as it is not likely that you know what the "pitch" of a thread is, it may be as well to tell you that it means the distance apart of the threads. Here, for instance, you see a thread having $\frac{1}{4}$-inch pitch, or, what is the same thing, a pitch of 4 per inch, as it is more often termed. Sometimes, too, the iron-worker uses a thread having a "double" or a "treble" pitch, which means that instead of being formed of one continuous spiral it is formed of two or three spirals, one of which you see at A, and the other at B, which is carried as far as the point C. So you see that a double thread winds forward twice as fast as a single one. The standard or universally accepted forms of thread used by English machinists is the rounded top and bottom, or Whitworth, thread, while the standard American thread has a flat top and bottom. Then we have, too, the square thread, that is used in all countries, and the ratchet thread as well as the right and left hand thread.



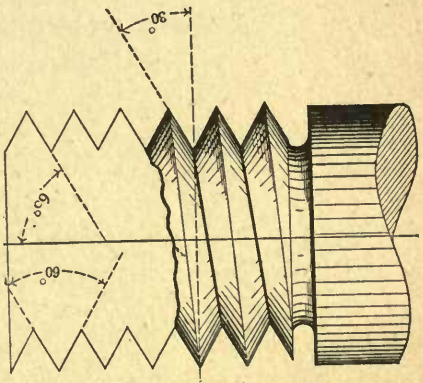
THE PITCH OF A THREAD.



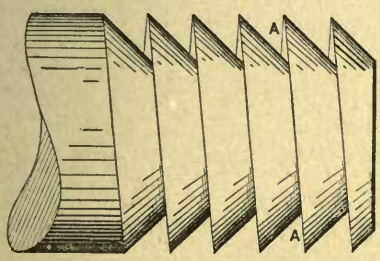
A DOUBLE THREAD.



THE ENGLISH STANDARD THREAD.

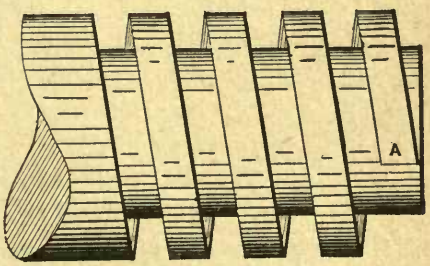


THE AMERICAN STANDARD THREAD.



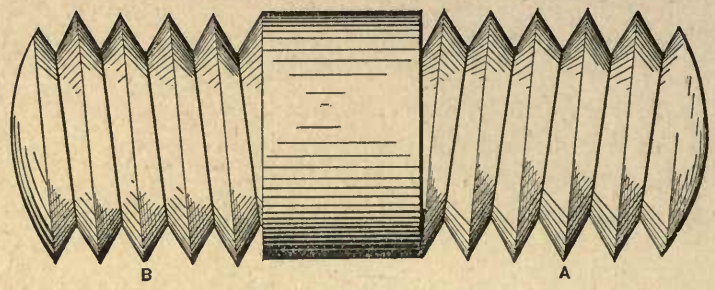
THE RATCHET THREAD.

These screws are cut in many different ways. For instance, the jeweller cuts them upon his small screws by hand with a "screw-plate," which is a steel plate containing different sizes of holes, with a screw or thread cut in them, and with notches cut in their sides to give the cutting edges. All he has to do is to place one of



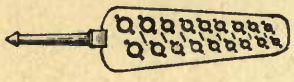
THE SQUARE THREAD.

these holes on the end of the blank and turn the plate around, and it passes down the screw and cuts a thread on it. But such a tool does not cut sharp enough for large screws; so the machinist uses a stock and die—the stock being a lever holding two dies, which may be opened or closed with a set-screw so that he may wind the stock up and down the bolt, taking a separate cut each time until a fully cut thread is formed.

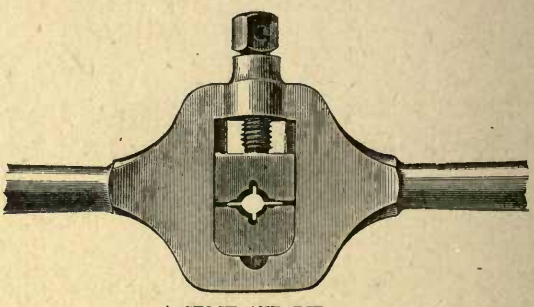


A RIGHT AND LEFT HAND THREAD.

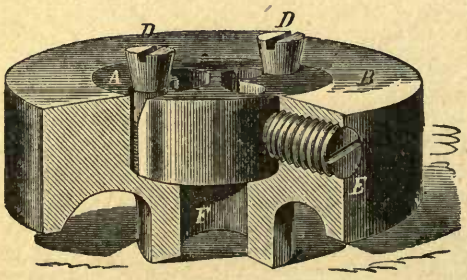
In other forms of die, however, the full depth of thread is cut by one passage of the dies down the work; and as the dies wear larger means are provided to close them into their proper size. These are called solid or solid adjustable dies. There are two half-circular dies, A, held in a ring or collet, B; two screws, D, serve to keep the dies apart, and two more, E, are used to close them in, so that by means of screwing up or unscrewing these four screws the size the dies will cut may be adjusted.



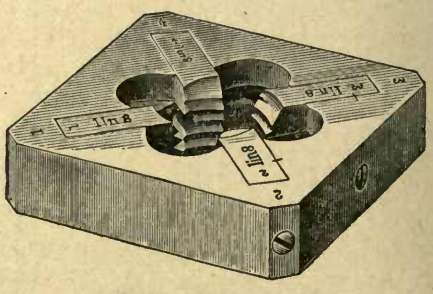
A SCREW PLATE.



A STOCK AND DIE.



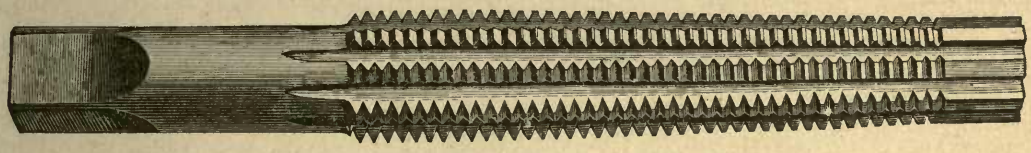
ADJUSTABLE DIES.



A SOLID ADJUSTABLE DIE.

But by far the larger part of machinists' screws are cut in machines, and in these square adjustable dies are then often used; the screws at the corner being to set the four bits, or "chasers," that cut the thread, while these "chasers" are readily removable to grind them sharp again when they get dull.

So far we have only spoken of the tools used to cut threads on the outside of bolts, but here we have the "tap," or tool used to cut threads or screws in holes. This, too, is simply pressed into the mouth of the hole and revolved, and down it goes, burying itself into the iron with a terrible grip, and requiring a good deal of hard work to turn it by hand.

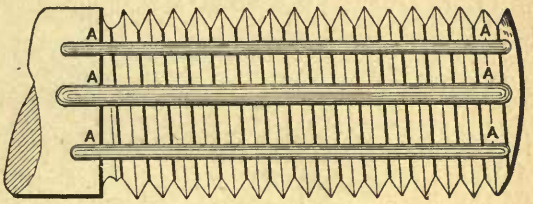


A MASTER TAP OR HOB.

Not much hand-tapping is done nowadays, because it is too slow and laborious an operation. The solid dies of which we have just been speaking are cut or threaded by a master tap, having more flutes and so more teeth than the hand or machine tap.

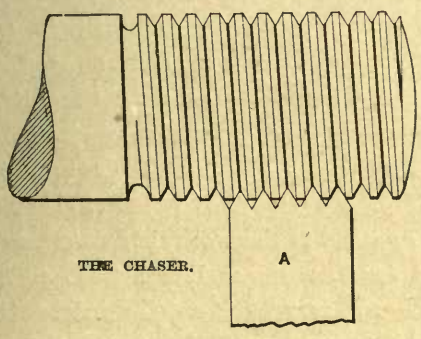
The hand turner cuts threads in the lathe with a comb or chaser, A, which he pushes

THE HAND TAP.

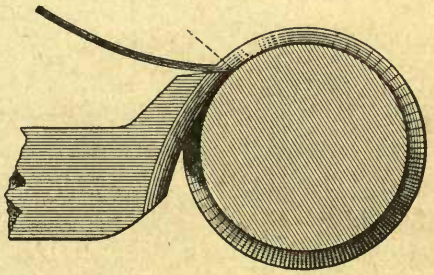


A HOB.

against the revolving work, causing its teeth to cut the grooves necessary to form a thread. The chaser is cut in the same way by pushing it against a hob, or hub, as some call it. It is a rare thing to see a thread chased by hand in these days of self-acting lathes and screw-cutting machines, for the lathe can move the chaser along and take a heavy cut much more



THE CHASER.



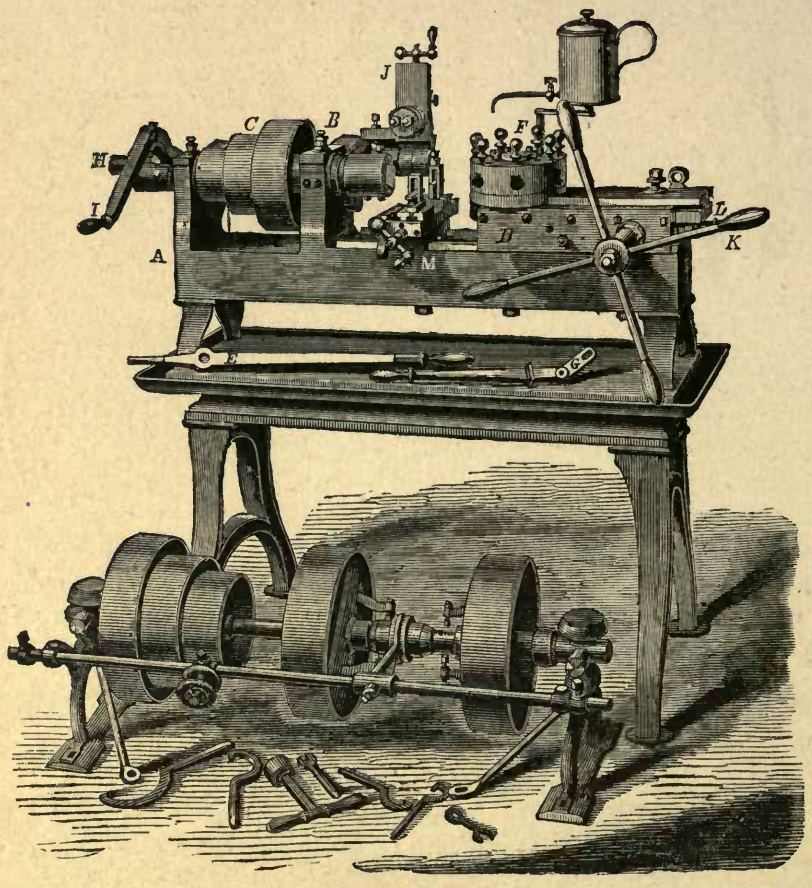
SINGLE-POINT TOOL.

easily than a workman can; and for sharp-pointed threads a single-pointed tool is used, cutting out a long curly shaving much thicker than the chaser used by hand could do.

There is another kind of screw, used by the machinist, with which you may as well become acquainted, its name being the "machine screw." Now whether it got this name

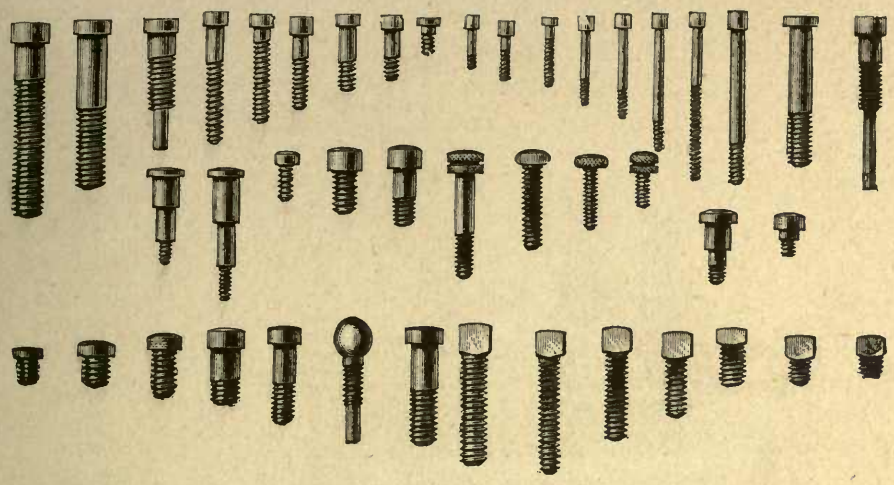
from being made in a machine, or because it is mostly used about the different parts of machines, it is hard to say; but it is made in many forms, as, with square-heads, button-heads, etc., and in most cases has a screw-driver head—that is to say, a head with a slot or saw-cut in it to receive a screw-driver.

The machine for making machine-screws is aptly enough called a screw-machine, its main difference from an ordinary lathe being that it possesses what is called a "turret-head," although some call it a "monitor-head;" these names evidently having been given it from its resemblance to the turret of a monitor war-ship. In each of the holes of this "turret" a tool is placed, and all the workman has to do is to place through the "live spindle," H (which is hollow all the way through), a rod or bar of iron to make the work from, and grip it in the chuck. When he pulls the long handle over to the left the monitor-head glides forward and the first tool operates on the end of the bar. When the turret has moved forward until it comes against a stop, and can go no farther, the workman pushes the handle back, moving the turret back and causing it to revolve enough to bring another tool opposite to the work, and so on, so that by operating the lever back and forth one tool after another comes into action, each one performing some special service, and finally the slide-rest is used to cut the finished work off the bar or rod, and it falls below. You would be very much interested and quite surprised to see how quickly this machine does its work, and what a great deal of labour it saves. But it requires rare skill and fine workmanship to make it. Indeed, it would be interesting if we could know how many hundreds of hours of thought have been devoted by machine designers to produce it in its most efficient and handy form. You must not,



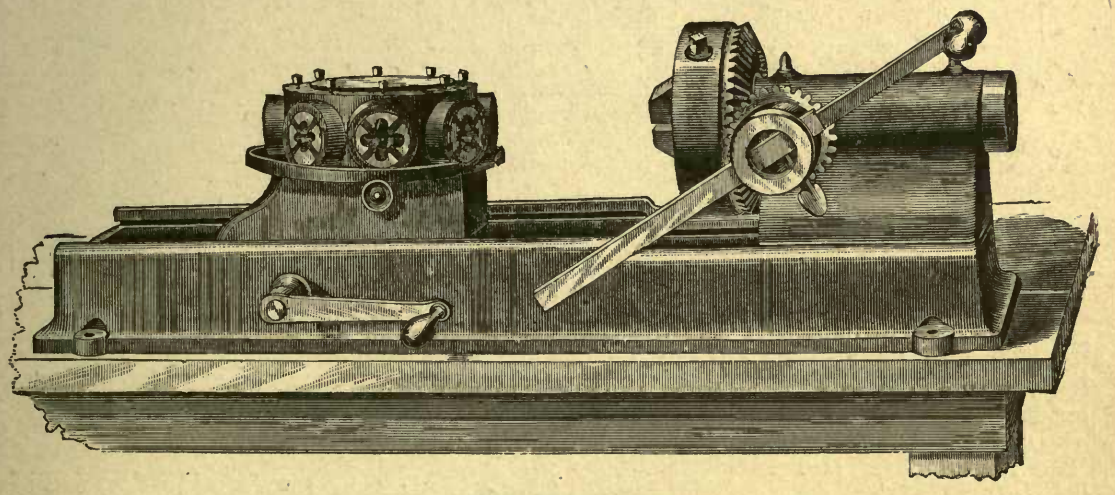
A SCREW-MACHINE.

however, suppose that this is the only form of machine used for making work having screw-threads upon it, or that it is used for making screws only; for it will make any kind of round work that can be cut out of a rod of iron.



SCREWS MADE IN THE SCREW-MACHINE.

The common bolts that you see in the machine-shop are threaded in a screw-cutting machine that is commonly called a "bolt-cutter." It is made to be either used by hand or driven by a belt or strap. In the hand bolt-cutter the workman winds around the long lever, and this causes the work to revolve; then he winds the shorter handle and the turret-



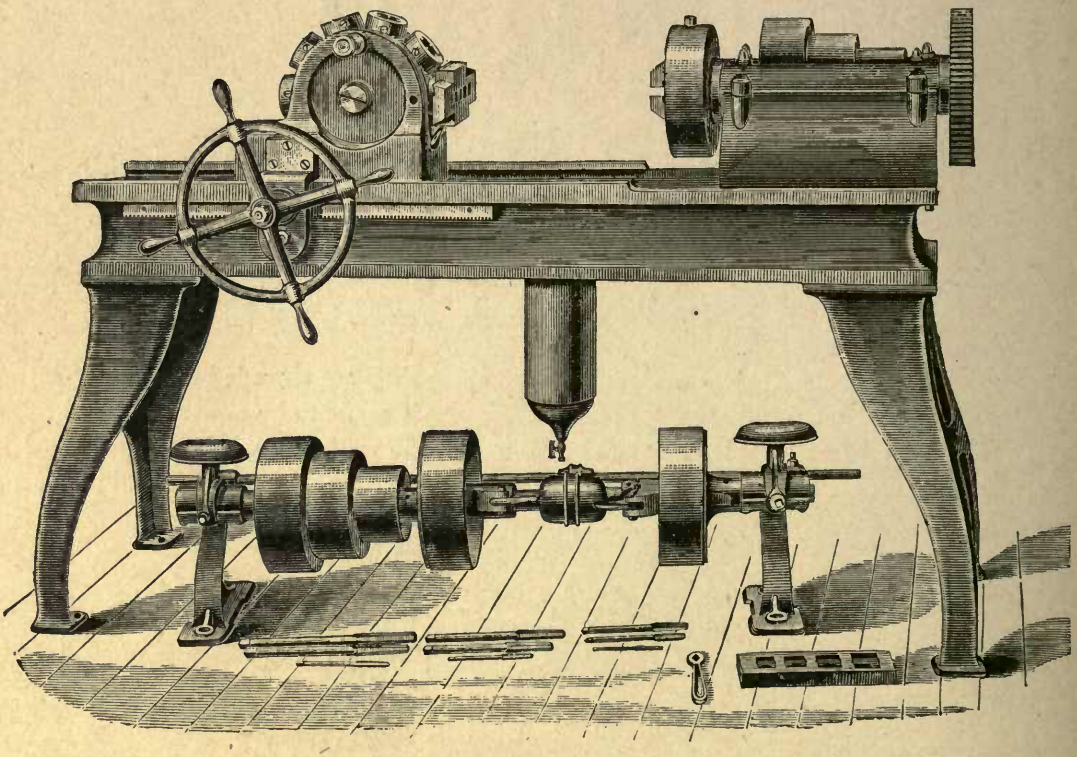
A HAND BOLT-CUTTER.

head advances and forces the die upon the end of the bolt or work. This is tiring work, unless the screws are small ones; so hand machines are not used when power-driven ones can be afforded or are at hand.

In the power machine all the operator has to do is to wind the handle and thus pull

the turret-head to the work. In both machines the turret can hold, as you see, several sizes of dies, or other tools if necessary, which may be used to round up the end of the bolt, cut off a part of its thread, or perform any other operation that may be possible in a machine that advances the tool from the end of the work.

In the nut-tapping machines there are sometimes three or four spindles, all driven by one belt, and each driving a separate tap, which is supplied with oil from a pump that forms a part of the machine. The nuts are held in the three heads or frames you see at the right-hand end of the machine, and are forced on the ends of the tap by the upright hand-

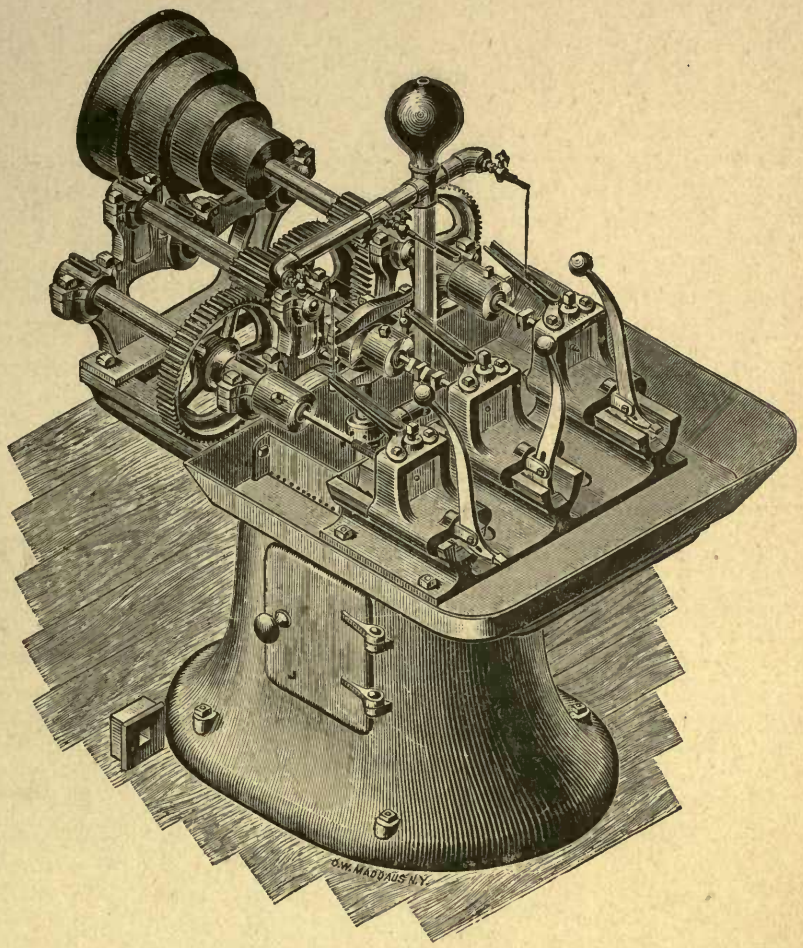


A POWER BOLT-CUTTER.

levers. But as soon as the tap gets a fair hold upon the nut it will pull it forward itself and finally string it on the tap shank. After three or four nuts have become thus strung the tap is removed to take them off, so that what with putting the nuts in and taking them out the workman is kept pretty busy, as you can well imagine.

The most wonderful machine ever made for screw-making is one used by the watch manufacturers. One of these machines will make 5000 screws complete in a day, and one girl can attend to ten machines. But you can hold all the screws a machine can make in a day in your hands, for it takes about 9000 of them to weigh an ounce. Now you can imagine what a tiny little screw it must be that weighs only the nine-thousandth part of an ounce, and just think with what great precision the machine must work to make such little midgets.

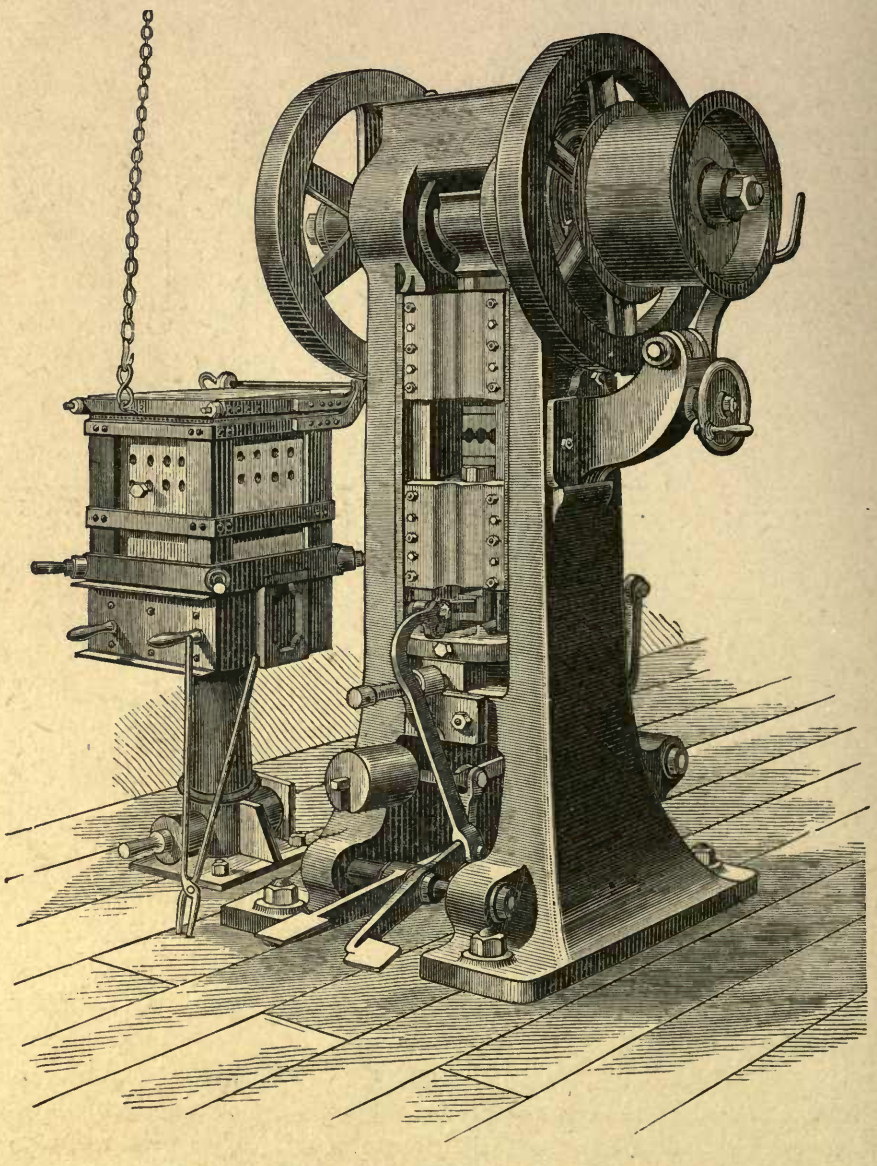
A coil of polished wire is suspended at the end of the machine, its end being passed through the hollow spindle and into the chuck, and the machine is then started. First a diminutive tool comes forward and trims off the end of the wire, and as soon as it retires another comes forward and cuts down the stem, thus leaving a head; as soon as this tool recedes a third hops out and cuts the screw. A fourth nearly cuts it off, leaving the head of the proper thickness; and then comes forth a pair of mechanical fingers which take hold of the screw, break it off, and carry it to another part of the machine, where a revolving saw advances and cuts the slot for the screw-driver. These operations follow one another rapidly but with great precision, all the attention the machine requires being to supply it with oil and with a new coil of wire when necessary. In producing machines of this kind, or at least in bringing them to perfection, years of thought and deep study are involved, for the machine that looks well and perfect so far as the drawings show may not be a perfect success when put to every-day work and to the test of time. Sometimes a failure of a newly-designed machine ruins the designer, but points out the road to success to another inventor, who therefore profits by the first failure. Indeed, successful inventing or designing depends very largely upon first ascertaining what has already been done by others so as to know what has succeeded and what has not. Very few important machines maintain their original form of design, as experience in their use points out where improvement can profitably be made.



A NUT-TAPPING MACHINE.

The busy brains of the inventor, to whom we owe so much of our advancement in machine construction, have also been brought to bear upon the making of screws without

the intervention of the screw-turning or screw-cutting machine, and machines have actually been made in France that forge the coarse-threaded screws called "lag-screws," which are used for holding heavy pieces of timber together. Indeed, there seems no reason to doubt that as man increases his knowledge and facilities in the processes of machine



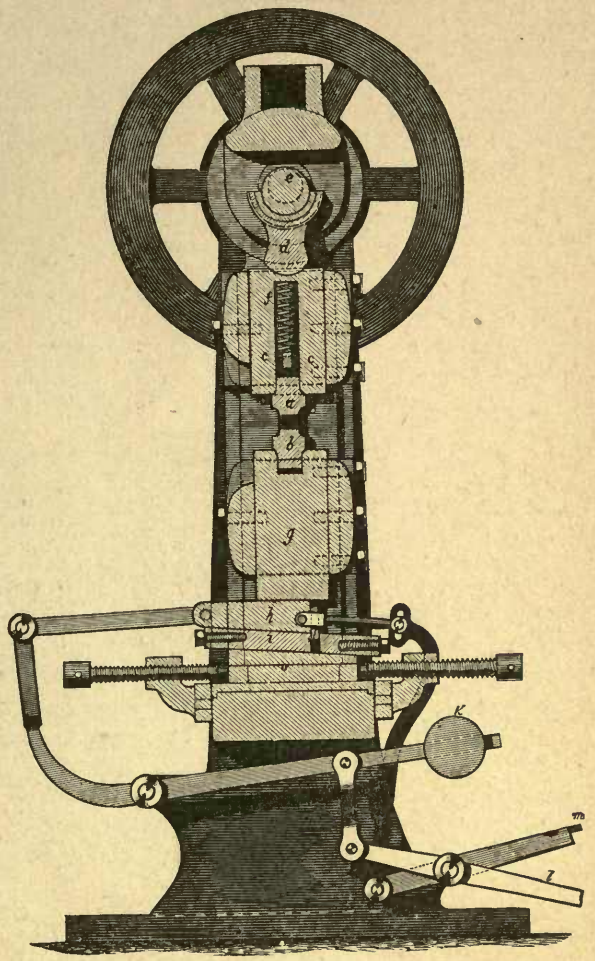
VIEW OF THE SCREW-FORGING MACHINE AND ITS FURNACE.

forging, much of the work requiring costly machinery to cut it cold will be forged and pressed into finished shape while heated.

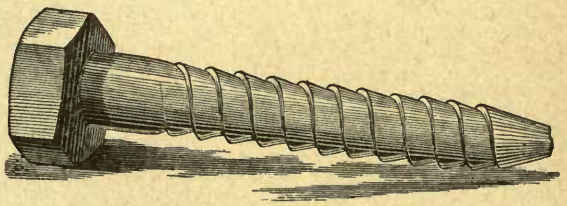
Indeed, in some of the machine-shops of New England much plain work, such as the iron handles that are fitted to the hand-wheels of lathes, planing-machines, and drilling-

machines, is now beautifully finished by forging operations. The dies in which such finishing is done are carefully smoothed, and the work comes from them having a pale blue, and looks something like the blued parts of rifles.

You must know, however, that whenever forged work is to be brought to this state of perfection the final finish must be made at about the time the iron is losing its red heat, and that it requires to be hammered very quickly while it cools to black heat. During the whole of the forging the scale that forms on the surface when the work is red-hot must be carefully cleaned off, and water must be applied to keep the work surface free from scale, which it does very effectively if it is liberally supplied. Perhaps you have heard a loud report, like that of a gun, follow the striker's blow after the blacksmith has dipped his "swage" in his water-pail, and this is caused by the water flashing into steam when driven forcibly against the red-hot iron.



THE MECHANISM OF THE SCREW-FORGING MACHINE.



THE FORGED SCREW.

But to return to our screw-forging machines. The screws are simply revolved slowly between a pair of "dies" having the necessary screw-thread in them, and are thus pressed into shape, being of the proper diameter when the faces of the dies meet under the rapidly falling blows of the upper die, which is operated by a belt upon the fly-wheel at the top of the machine. The furnace stands close to the machine, so as to be close at hand and not give the screws time to cool. The mechanism of the machine consists of a series of foot-levers to adjust the height of the bottom die and to lower it down to get the finished screw out, and a revolving shaft with a cam to work the top die, which strikes its blows very quickly indeed, so that they make considerable clatter, as indeed all forging machines do.

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